ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

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Why Another Botanical Magazine?

To serve as a common meeting place for botanists, interested primarily in fundamental principles, and others who are concerned with economic applications of those principles and with the industrial utilization of plants and plant products.

WILLIAM J. ROBBINS
Director, The New York Botanical Garden

MAN has always been dependent upon plants for his food, the oxygen he breathes, for fuel, for clothing, for much of his shelter, for various medicines and for innumerable comforts and conveniences. Without plants there would be no animal kingdom, and man himself could not exist. This basic economic importance of plants is recognized in the name used for the scientific study of plants—Botany—which is derived from a Greek word meaning to eat, and the early history of botanical science shows clearly its origin in the use of plants for food and for medicine.

From plants we obtain linseed oil, corn and coconut oil, turpentine, lacquer, varnishes and resins, coffee, tea and other beverages, perfumes, flavorings and spices, drugs and insecticides, paper, cordage, cellulose for artificial silks and a hundred other useful products. How much of our economy depends upon many of these plant products, some from distant places, was emphasized by our experience during the past war which cut us off from normal supplies. Rubber and quinine are two of the products, the shortage of which was felt most keenly, but there were many others, for example, the sponge of the luffa gourd, the insecticide pyrethrum, chicle for chewing gum, the drug ergot, agar agar and cork. On the detrimental side, bacteria, yeasts and molds cause disease in other plants and in animals and man, rot wood and cloth, mold food, short-circuit electrical instruments and deteriorate optical equipment in the tropics.

Another way in which plants contribute to our economic system is through the association of microorganisms in the formation of various products, for example, cheese, the production of which depends upon the activity of the lactic acid and other bacteria and various molds; beer, wine and other liquids fermented by yeast; sauerkraut, vinegar, soy sauce and many others less well known or desirable. Bacteria, yeasts and molds, as we learn to know them better, are increasingly used for producing specific chemical compounds which are beyond the skill of the laboratory worker or which can be made more cheaply by the microorganism. Alcohol, acetic acid, acetone, glycerine, citric acid, gluconic acid and riboflavin are some of these compounds. The most recent and illustrious additions to this list are penicillin and streptomycin.

In spite of the essential importance of plants for our existence, periodical magazines devoted exclusively, at least by title, to the economic values of the plant kingdom are few in number. The journal *Angewandte Botanik—Zeitschrift für Erforschung der Nutzpflanzen* was initiated in 1919, *La Revue de Botanique Appliquée et d'Agriculture Tropicale* begun in 1901 and the *Revue des Cultures Coloniales* founded in 1897. Other

journals of more general scope include articles on economic botany, for example, *The Chemurgic Digest* and *The Journal of Agricultural Research.* Still others, as those concerned with plant diseases and various aspects of horticulture, deal to a considerable degree with specialized fields of applied botany. However, unless others have escaped my attention, periodicals which endeavor to cover the field of plant utilization in a more or less all embracing manner are few indeed.

In an effort to remedy this paucity of periodical information on an academic level in America, there now appears ECONOMIC BOTANY, of which this issue is the first number. The particular name selected for this journal is of relatively minor importance, for it might as well have been titled by some other term to indicate that it is concerned with furthering the application of the knowledge of plants in general to human affairs.

It is not necessary to elaborate further on the importance of plants to man and on their number and variety, nor to emphasize that the potentialities of the plant kingdom still to be developed are limited largely by our knowledge of it and our desire and ability to use that knowledge. It must be realized, however, that knowledge is one thing and its application to human problems another. The individual or group with the requisite knowledge may be unfamiliar with or uninterested in practical problems, and, on the contrary, the man confronted by a problem may be unacquainted with the knowledge he requires to solve it.

A journal of applied botany is therefore needed to bridge the gap which always exists between knowledge and its application, between those interested in knowledge for its own sake and those interested in it because of its usefulness. This can be accomplished, in part, by publishing information on plants of potential economic importance, on the less well known methods and facilities by which plants and plant products are used, on problems encountered in utilizing botanical materials, on botanical principles which may be of practical significance, and on many other subjects which space here does not permit to be enumerated.

Of course, it is not possible nor desirable to separate sharply botany from economic botany. This is generally true of so-called pure and applied science. The investigator of a problem of importance to industry may discover principles of general application and thus add to the total of knowledge in that field; the scientist driven only by his own curiosity or his dissatisfaction with answers to questions which have no immediate application may uncover information which becomes the basis of a new industry or makes an old one more effective. Pasteur, for instance, did not hesitate to investigate the spoilage of beer, diseases of silk worms or anthrax of cattle and sheep, problems of practical importance. Yet his discoveries gave us fundamental concepts which opened an entire segment of biological science. Furthermore, an investigation of the genetics of the fruit fly or of the pink bread mold establishes principles which may be applied to the breeding of wheat and cattle.

To develop a journal which will serve, in a sense, as a common meeting place for botanists, interested primarily in fundamental principles, and those concerned with their application and development is highly desirable in today's ever increasing state of technological specialization. It is the purpose of ECONOMIC BOTANY to meet this need, as well as to provide information for those who value knowledge purely for the sake of learning.

Hybrid Corn—*Science in Practice*

In the production of which, the application of genetical knowledge and technique has increased the American corn crop billions of bushels, worth billions of dollars.

GORDON MORRISON*
Burgess Seed and Plant Company, Galesburg, Michigan

THANKS to hybrid seed, many more bushels of corn of better quality are now produced nation-wide on fewer acres than formerly and at much less cost per bushel in terms of man power. This gratifying state of affairs derives from a discovery made more than forty years ago by Dr. George Harrison Shull. Shull was then engaged in research in pure science at the newly established Station for Experimental Evolution of the Carnegie Institution of Washington at Cold Spring Harbor, Long Island, New York.

Following the rediscovery of Mendel's Laws Shull set out to discover the basic principles of the origin and inheritance of new characters. His primary purpose in studying corn was to determine the effect of inbreeding upon the inheritance of numbers of rows of grains on the ears. In the course of his experiments Shull isolated numerous highly inbred lines of corn. Manifestations of hybrid vigor in the progenies from controlled crosses between highly inbred lines impressed this farm-bred researcher that he was dealing with a principle of tremendous practical importance. Shull realized that he had within his grasp an improved method of corn breeding; a means of realizing higher yields of corn through utilizing hybrid vigor.

Shull called his new corn-breeding technique "A Pure Line Method in Corn Breeding". However, the end product of this new method of corn breeding—namely, seeds for farmers' use—has become known throughout agricultural science and industry as "Hybrid Corn" or as "Crossed Corn", since the seed crop is indeed hybridized-corn or crossed-corn.

What is a Hybrid?

Some readers may feel that undue liberties have been taken by corn breeders in such use of the term "hybrid". The term was used by earlier biologists and laymen to designate the offspring from a cross between members of different species. Thus the mule is a hybrid of the horse and jackass.

Modern plant breeders use the word "hybrid" to designate all cases in which the parents differ in one or more hereditary traits. Thus when we cross varieties of garden bean that differ in color of pods we may say that the first generation offspring are hybrid for wax and green pod color.

Hybrid Corn is a Special Kind of Hybrid

In Hybrid Corn the term "hybrid" is used in a very special sense. It desig-

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nates corn seed which is the result of *completely controlled* crossing of chosen uniform inbred strains. Good hybrids that find use in agriculture are derived by crossing and testing large numbers of inbreds. This serves to disclose those combinations of inbreds which impart to their hybrid offspring unusual vigor and capacity for relatively high yields of grain and fodder. Adapted hybrids commonly produce yields 10% to 30% greater than the corresponding open-pollinated varieties under similar circumstances.

There are several kinds of corn hybrids in use in practical agriculture, including single crosses and double crosses. Hybrid Corn seed of commerce is not made hybrid by controlled hand crossing but by a dependable field method outlined in the section devoted to the technique of mass production of Hybrid Corn.

For a technical discussion of the little understood but very valuable phenomenon of hybrid vigor the reader is advised to consult "Hybrid Vigor and Corn Breeding" by F. D. Richey, which appeared in the September, 1946, issue of the Journal of the American Society of Agronomy.

History of the Origin of Hybrid Corn

Shull's first major experiment at the Station for Experimental Evolution was devised in 1904 to determine what influence the method of breeding has on the production of mutations and on their frequency of occurrence. For this purpose Shull obtained a foundation stock of Evening Primrose collected in the wild by Hugo de Vries.

De Vries had differentiated sharply two kinds of variation, namely, mutation and fluctuation. It seemed desirable to Shull, in connection with his experiments on the effects of cross and self fertilization on mutations, to study also the relative influence of cross fertilization and self fertilization on the extent of fluctuating variation in a cultivated plant such as corn. Shull chose as an ideal object for such an investigation the numbers of rows of grain on the ears of corn.

Since Shull had started his research with previously unstudied Evening Primrose it seemed desirable to start the

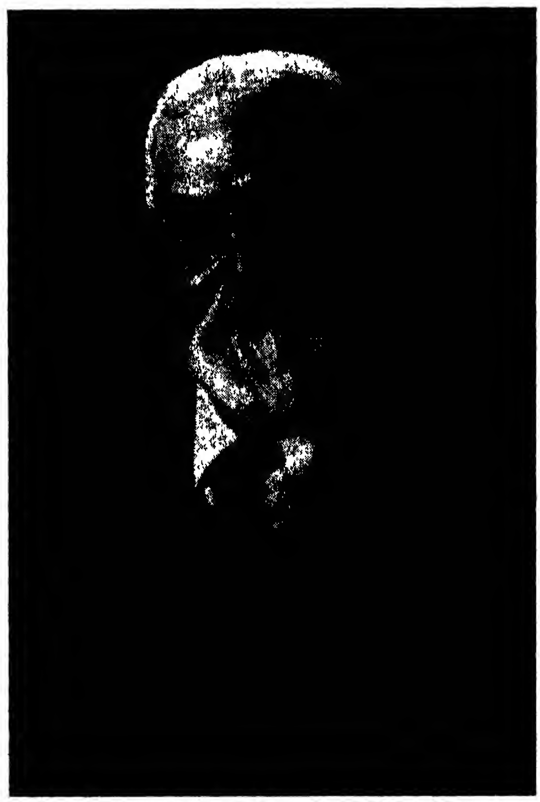

FIG. 1. George Harrison Shull, originator of Hybrid Corn, whose genius in obtaining highly inbred lines of corn and in producing hybrid vigor by crossing such inbred lines, made possible larger acreage yields of better corn and laid the foundation for an industry which from 1942 through 1945 produced an increase in the national corn production amounting to more than $2,000,000,000.

work with corn in the same manner. So he proceeded to count the rows of grains on the ears of several bushels of corn that the station had bought as horse feed. He saved ears for planting which belonged to each row class, from the lowest to the highest row number. There

was no preconception on the part of Shull that he was destined in this experiment to lay the foundation for a major improvement in farm technique that would make possible the production of more corn on fewer acres and with less labor. That does not mean, however, that Shull did not realize the importance of such improvement in agricultural techniques. If he had been actually aiming at such improvements, he probably would have given up the experiment when he found that each successive generation of inbreeding resulted in deterioration in yield as compared with the preceding generation. Since Shull was not interested at the time in an *increased yield*, but only in the question "What will happen?", he was intrigued tremendously in noting the fact that each successive generation of controlled self pollination in corn produced *less* deterioration than the one preceding. This led Shull at once to the view that a limit would be reached at which further deterioration would not result from continued inbreeding. Already by 1907 the segregation of strikingly unlike lines made the conclusion inevitable to Shull that he was deriving many distinct biotypes from what seemed like merely a fluctuating series of variations in a population. During the summer of 1907 Shull explained the situation in detail to various visitors including Dr. Edward Murray East.

Incidentally, it needs to be said here, in the interest of historical accuracy, that East's name has often been linked in misleading manner with Shull's in relation to the origin of hybrid corn. Much of the literature, particularly genetic text books and popular books on plant improvement, have implied or stated specifically that Shull and East arrived at the same conclusions about hybrid corn simultaneously and quite independently of each other. As a matter of fact, Shull and East began working with self-fertilized lines of corn at about the same time, namely about 1905, but at different experiment stations and entirely independently. Shull based his proposals for Hybrid Corn solely upon his own experiments. These proposals remain today the basis of the development of Hybrid Corn seed as it is produced for nationwide use on more than half of the national corn acreage. On the other hand, East minimized the importance of Shull's proposals by stressing the fact that the experiments had been conducted on a small scale and that the conclusions, although probably scientifically correct, were of no practical value. Indeed, East, as late as 1912, recommended crossing of varieties as the most practical means of utilizing hybrid vigor, thus leaving Shull's proposal the only one which advocated seriously the utilization of inbreeding as a preliminary phase of the production of hybridized seed corn.

In announcing his early experiments that served to inaugurate a new era in corn breeding, Shull prepared in 1907 his first paper on corn breeding for the American Breeder's Association. This paper, entitled "The Composition of a Field of Maize", was read at the annual meeting in late January, 1908, in Washington, D. C., and was published later the same year in the Proceedings of the American Breeders' Association.

The next year, 1909, Shull read his epochal paper, "A Pure Line Method in Corn Breeding", before the American Breeders' Association, assembled in Columbia, Missouri. This paper was published in the yearbook of the American Breeders' Association, Volume 5.

In the course of his studies on the origin and inheritance of new characters, Shull discovered that by inbreeding to isolate pure breeding types he was indeed determining by genetic analysis the hereditary composition of a field of corn.

In the American Breeders' Association article of 1908 Shull reasoned that the

difficulties, such as lessened size and vigor, that had often been encountered in attempting to improve open-pollinated crops by inbreeding, could hardly be explained by the harmful effects produced by the accumulation of disadvantageous individual variations. Many crops, including peas and beans, wheat and barley, have been naturally and exclusively or almost exclusively self-pollinated for countless generations with no apparent ill effects. Shull deduced that continued self-fertilization simply isolates, in due time, various pure-breeding "biotypes" or strains by separating them from hybrid combinations. Thus the differences between inbreds is due to the different hereditary factors possessed by the various inbreds.

Shull concluded in 1908 that the fundamental problem in corn breeding is the development and maintenance of that hybrid combination which possesses the greatest vigor, since the most important characteristics for which the corn breeder strives are those closely related to the question of physiological vigor.

Impressed by the yields of inbreds compared with the greater yields and the remarkable uniformity of some first generation hybrids, Shull reasoned that separating and recombining of definite pure lines might yield valuable results.

Shull's Directions for Obtaining and Utilizing Hybrid Vigor in Corn

Based upon his own investigations and demonstrations, Shull suggested in 1908 the following procedure for the corn breeder interested in obtaining results of practical value:

(*a*) Obtain by controlled self-pollination as many self-fertilized ears as practicable of the variety he is attempting to improve.

(*b*) Continue selective inbreeding until strictly uniform lines have been established.

(*c*) Make all possible combinations of crosses between these inbred lines.

(*d*) Grow all first generation hybrid combinations in comparative tests and study them carefully as to relative yield and the possession of other desirable qualities.

(*e*) Maintain isolated plots for the continuance of those inbreds which provide the best combinations.

(*f*) Maintain an isolated plot for the production of crossed corn for growers' use as seed corn by growing inbreds in alternate rows and detasseling early the rows of the female parent which is to yield the crossed corn for growers' use.

Shull did not himself use the detasseling method he recommended to the practical corn breeders. All pollinations in both selfing and crossing were carried out with meticulous care by hand pollination.

It is significant that Shull's paper on his new method in corn breeding and his demonstration received scant acclaim from his corn belt audience. Had his listeners seen through the rather clear though necessarily academic demonstration, they could have advanced practical corn growing at once. They could have avoided a lag of fully a quarter-century in the ultimate utilization of hybrid vigor in corn growing. It is true that Shull used in his studies and in his demonstrations ordinary field corn from the eastern seaboard. Shull's relatively vigorous hybrids were far superior to their inbred parents and were equal to the best specimens in the ordinary field from which the initial selections had been made. Nevertheless, the audience included conservative, skeptical corn growers who saw Shull's vigorous hybrids as scrubby things indeed compared with the tall, large-eared corn-belt varieties. The apparent failure to foresee that the same percentage gains might be realized with local varieties as Shull demonstrated with eastern types held progress in check.

One important difficulty was encountered in carrying out Shull's program in

practice. Many valuable inbreds are by nature very low yielding, and thereby, when crossed to produce hybrid seed, the yield of first generation hybrid seed for farmers use is so low that seed production is unprofitable. This difficulty was overcome by Dr. D. F. Jones, the brilliant geneticist who has specialized in corn breeding at the Connecticut Agricultural Experiment Station for many years. Jones retained Shull's pure-line idea intact and went a single logical step forward by proposing that two first generation hybrids—each derived from a pair of inbreds—be utilized by crossing them again similarly. Thus hybridized seed corn needed by the farmer could be produced upon the highly productive first generation hybrid instead of upon the relatively unproductive inbred used as the female parent in the first field crossing plot. Jones's proposal of the "double cross" or "4-way cross" reduced greatly the cost of seed production and has long proved of tremendous practical importance.

When Jones first arrived at New Haven he was quite surprised to see that Hybrid Corn was not being used. Jones got together all of the available inbreds and put them in a small crossing plot on the Mt. Carmel farm in 1916. A few inbreds yielded 20–30 bushels per acre of seed but most of them were very low. The combination that gave the best single cross hybrid yielded only about two bushels of seed. Jones saw that this was prohibitively expensive, and the seed was so poor in quality that farmers would not plant it. Having on hand single crosses of distinct type it seemed worthwhile to cross these again. Accordingly a small crossing plot was grown in 1917 with the best Leaming single cross as pollinator and several other single crosses as seed parents. When tested in 1918 the combination of Burr White $(020 \times 022) \times$ Leaming (0243×0242) gave outstanding results. This was tested several years in trials at the station farm and in farmers' fields.

Hybrid Corn seed was first produced for commercial use by George S. Carter, Clinton, Connecticut, in 1921. The amount of seed was not large at any time but was widely distributed until the western hybrids came into production about 1930. These proved to be so

FIG. 2. Donald F. Jones, geneticist and resourceful field technician, whose device of the double cross, *i.e.*, the field crossing of first generation hybrids, overcame the objection of low yields of hybridized seed and made possible the profitable practical use of Shull's method of Hybrid-Corn seed-production for widespread use by corn farmers.

satisfactory and were produced so much more cheaply in the west that soon most of the hybrid field corn grown in the east was of western origin.

However, in February, 1945, research workers interested primarily in the northeastern States met at New Haven, Connecticut, to consider problems of corn improvement primarily concerned

with genetics and to develop a coordinated program of corn research in the northeastern area that will promote the production of corn hybrids with as wide usefulness as possible.

Henry A. Wallace and Hybrid Corn

The name of Henry A. Wallace is prominent in the history of Hybrid Corn. Wallace's greatest contribution has been that of getting a large number of people enthusiastic about inbreeding and crossing of corn. He wrote many articles on the subject of hybrid corn which appeared in Wallace's Farmer. Wallace started the first commercial hybrid seed corn company in the Middle West in the mid-20's.

Development and Practical Production of Hybrid Corn Seed for Growers' Use*

Ordinary Reproduction in Corn

Corn is wind-pollinated in nature. The pollen is scattered at random on receptive silks. There is hardly one chance in a thousand that pollen which falls on a receptive silk was derived from the tassel of the same plant. Thus crossing is the rule rather than the exception. Any plant commonly sheds pollen from its tassels over a period of ten days to two weeks or more, a period long enough to assure, under most conditions, an abundance of fresh pollen for all silks of all ear-buds as the silks become receptive. The pollen germinates upon the silk, sending down a pollen tube through which the sperm reaches the egg to effect fertilization. Selecting an ear from a good plant is selecting a good female parent only, since each kernel on the ear may have been pollinated from a different male parent plant.

* In this section we are using freely as a reference and often quoting whole paragraphs directly from F. D. Richey's excellent Farmer's Bulletin 1744, "The What and How of Hybrid Corn".

Selecting Inbred Strains

In selecting inbred strains for the purpose of making hybrid corn seed, good plants of one or more varieties of corn are self-pollinated. Pollen is placed on the silk of the same plant from which the pollen was collected. The best of the resulting ears are planted, an ear to a row, and good plants within these rows again are self-pollinated, and so on for several generations. Each year only the ears from the best plants from the best rows are selected for continuing the various strains.

During this breeding period all pollinations are made by hand. Ear shoots are protected from air-borne pollen by means of a small bag clipped over the young shoot before any silks have emerged. Translucent material, such as special glassine bags, enables easy frequent inspection to detect emergence of silks. As soon as silks appear a manila bag is placed over the tassels of the same plant. Within twenty-four hours enough fresh pollen will have been discharged to pollinate the emerging silks. The manila bag is bent over and removed from the tassel as carefully as possible to avoid influx of air-borne pollen. The ear bud cover is removed only momentarily and the pollen from the same plant is poured over the silks. The manila bag is then clipped over the ear bud promptly to reduce chances of influx of air-borne foreign pollen. Sometimes another manila bag is clipped over the tassels to provide means for a second pollination twenty-four hours later, which gives added assurance of a full ear of kernels.

With a continuation of selective inbreeding as described above there is a marked increase from generation to generation in the uniformity of the plants within any progeny row, although the differences from row to row become more and more distinct. Some strains are discarded almost at once because of grossly unfavorable characters. Promis-

ing strains are continued and usually breed practically true for whatever characters they possess after about a half dozen generations of selective inbreeding.

All characters of varietal significance respond to selective inbreeding, characters which tend to favor quality, yield, dependability under adverse circumstances, resistance to or tolerance of diseases and insects. Every plant of any strain that has been fixed by adequate selective inbreeding is practically like every other plant within the strain. After this it is unnecessary to self-pollinate in propagating a strain. Under adequate geographical isolation from other strains, natural pollination between plants of a given strain is then essentially like self-pollination.

Among thousands of inbred strains that have been isolated in this way none has been found to our knowledge which gives a yield as great as the open-pollinated variety from which the inbred was derived nor as great as an F_1 hybrid using that inbred, according to W. R. Singleton of the Connecticut Agricultural Experiment Station. Of sweet corn inbreds developed in Connecticut, their C27 inbred approaches the parent open-pollinated variety in yield as nearly as any inbred of record. Also, under certain conditions, their C13 inbred will give a yield almost as great as Golden Early Market from which it was derived. The Purdue inbred gives an exceptionally good yield. P39 and Purdue Bantam are the inbreds which yield Golden Cross Bantam, the single cross hybrid sweet corn developed by Glenn M. Smith and which is by far the most important sweet corn available to American growers.

H. K. Hayes, Chief of the division of Agronomy and Plant Genetics of the University of Minnesota, long famous as a corn researcher and director of practical corn breeding, is confident, however, that considerable progress is being made in developing more vigorous inbreds.

With sweet corn and popcorn it appears that inbred lines more nearly approach their crosses in yield than with field corn, although Dr. Hayes knows of no inbred line that is as vigorous as a good hybrid combination.

Finding Good Hybrid Combinations

Since a search for vigorous inbreds, coincidental with hybrid corn development, has not disclosed inbreds of sufficient merit in themselves, among tens of thousands observed, it is probable that for many years inbreds will continue to be developed almost exclusively as the means toward good hybrid combinations.

The breeder of hybrid corn must develop great numbers of inbreds and must know the characters he is dealing with and their mode of behavior in inheritance. He must make large numbers of crosses and test large numbers of hybrids to find those strains that combine best when used together. The inbred strains producing the poorer hybrids are discarded. Those producing the best hybrids are again crossed and the hybrids tested more adequately. Eventually through continued elimination and selection a few inbred lines are found that combine to advantage. Finally some two or three combinations that have been among the best in a given locality during several seasons are placed in commercial production.

Sometimes a pair of inbreds is found which yield, when crossed, a hybrid that is dependable under a wide range of conditions. Golden Cross Bantam sweet corn, developed by Glenn M. Smith, is a notable hybrid of this nature.

Different Kinds of Hybrids

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Different Kinds of Hybrids

Inbred strains may be combined into several different kinds of hybrids. Thus the single cross or hybrid is between two

inbred strains, the three-way cross involves three strains, the double cross four strains, and the top cross involves one inbred strain and one open-pollinated variety. Each of these has certain advantages and disadvantages or fits into the corn-breeding program in a particular way.

The simplest of these hybrids is the single cross, or hybrid between two strains. Thus, designating the female parent first in the customary way, B × A designates the single cross of strain B pollinated by strain A. The seed of the cross is that produced on the plants of strain B and usually will not appear noticeably different from self-pollinated seed of B. The vigor of hybridity becomes evident, however, shortly after germination begins if the crossed seed is planted.

The three-way cross is the F_1 hybrid of a single cross between two inbred strains and a third inbred strain. It is customary to use the single cross as the female and the third inbred strain as the male parent in producing a three-way cross. Thus, (B × A) × C designates the hybrid from a single cross B × A pollinated by strain C. The crossed seed produced on the vigorous B × A plants is superior in quality and quantity to that produced on inbred plants as in single crosses.

Double crosses are hybrids between the F_1 hybrids from two single crosses, involving four different inbred strains. Thus, the double cross or hybrid (B × A) × (C × D) designates the hybrid of the single cross B × A pollinated by the hybrid of single cross C × D. Here, both male and female plants are vigorous hybrids. The seed quality and production are high, and there is every possible assurance of abundant pollen from the male parent, which is not true when this parent is an inbred strain.

The cross of a commercial variety and an inbred strain has been variously designated as a top cross and inbred-sire cross. In limited experiments some such crosses have yielded more than ordinary varieties but less than comparable double crosses.

The make-up of double-cross hybrid seed is illustrated in Figures 3 and 4. The four ears labeled B, A, C and D (Fig. 3) represent the product of the inbred parent lines. If these are self-pollinated they will reproduce ears like those shown year after year. Seed from ear B, however, when pollinated with pollen from the plant producing A, produces the single cross B × A, shown immediately below its parents. Similarly the single cross C × D is produced from seed on ear C that was pollinated by pollen from plants producing D ears. The ears on the B × A plants, cross-pollinated by pollen from C × D plants, then provide the first-generation seed of the double cross (B × A) × (C × D), which is used in growing the ordinary corn crop. The ears at the bottom of Figure 3 represent what is produced in such commercial fields. The ears produced on the C × D plants grown to furnish pollen are used for feed or commercial corn. The seed from these ears may be planted to produce pollen-furnishing plants for another crossing block the next year. Such seed is referred to as advanced-generation seed and is equal to first-generation seed for producing pollen parent plants, but these will yield on an average only about two-thirds as much grain as the first generation.

The situation is perhaps clearer from Figure 4, which shows the system of crossing beginning with the inbred plants. Plant B is pollinated with pollen from plant A, and plant C is pollinated with pollen from plant D. Seed from these cross pollinations produces the single-cross plants B × A and C × D shown immediately below the parents. Plant B × A pollinated by plant C × D produces the double-cross hybrid seed

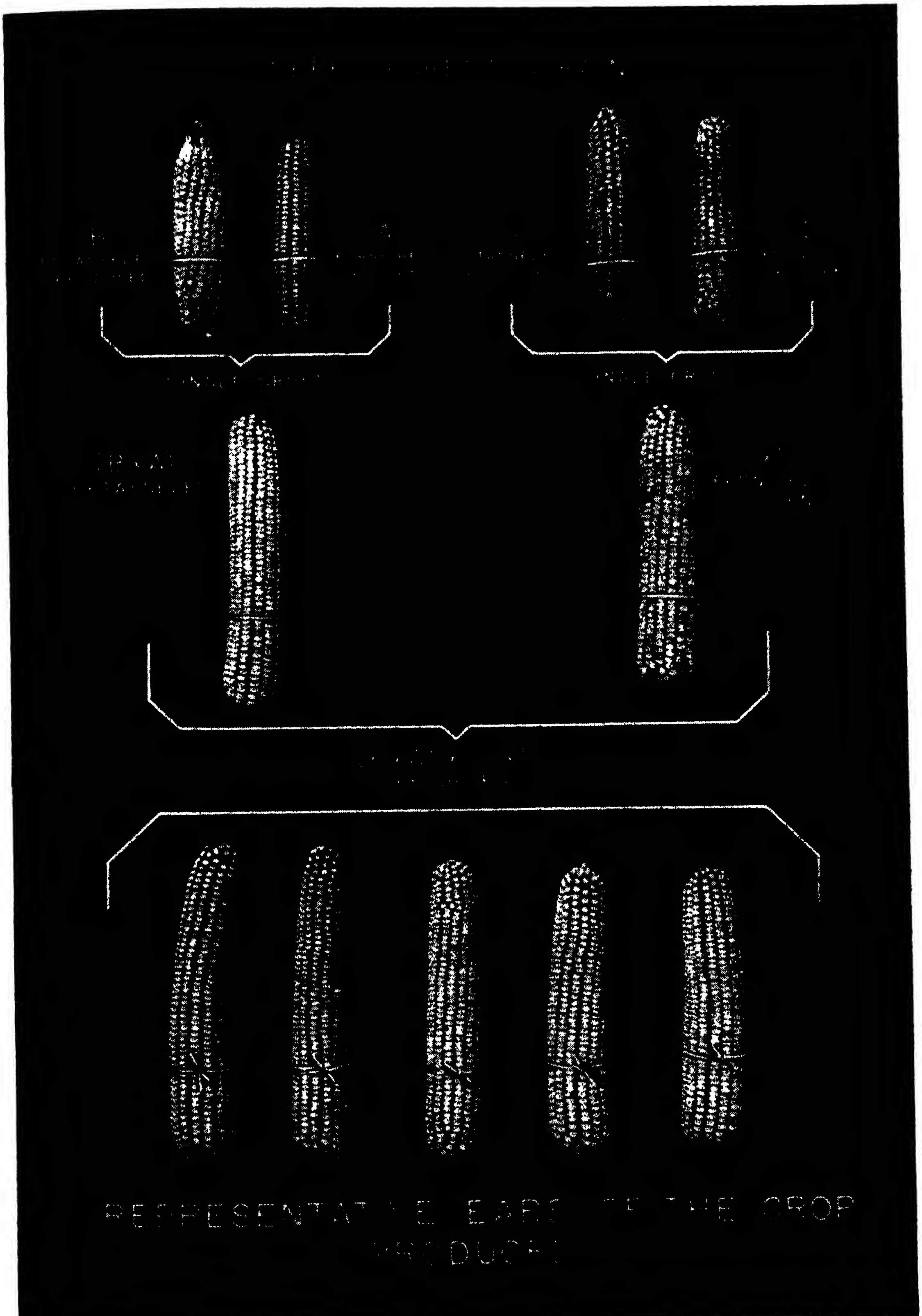


Fig. 3. Method of producing double-cross hybrid seed-corn, and representative ears of the

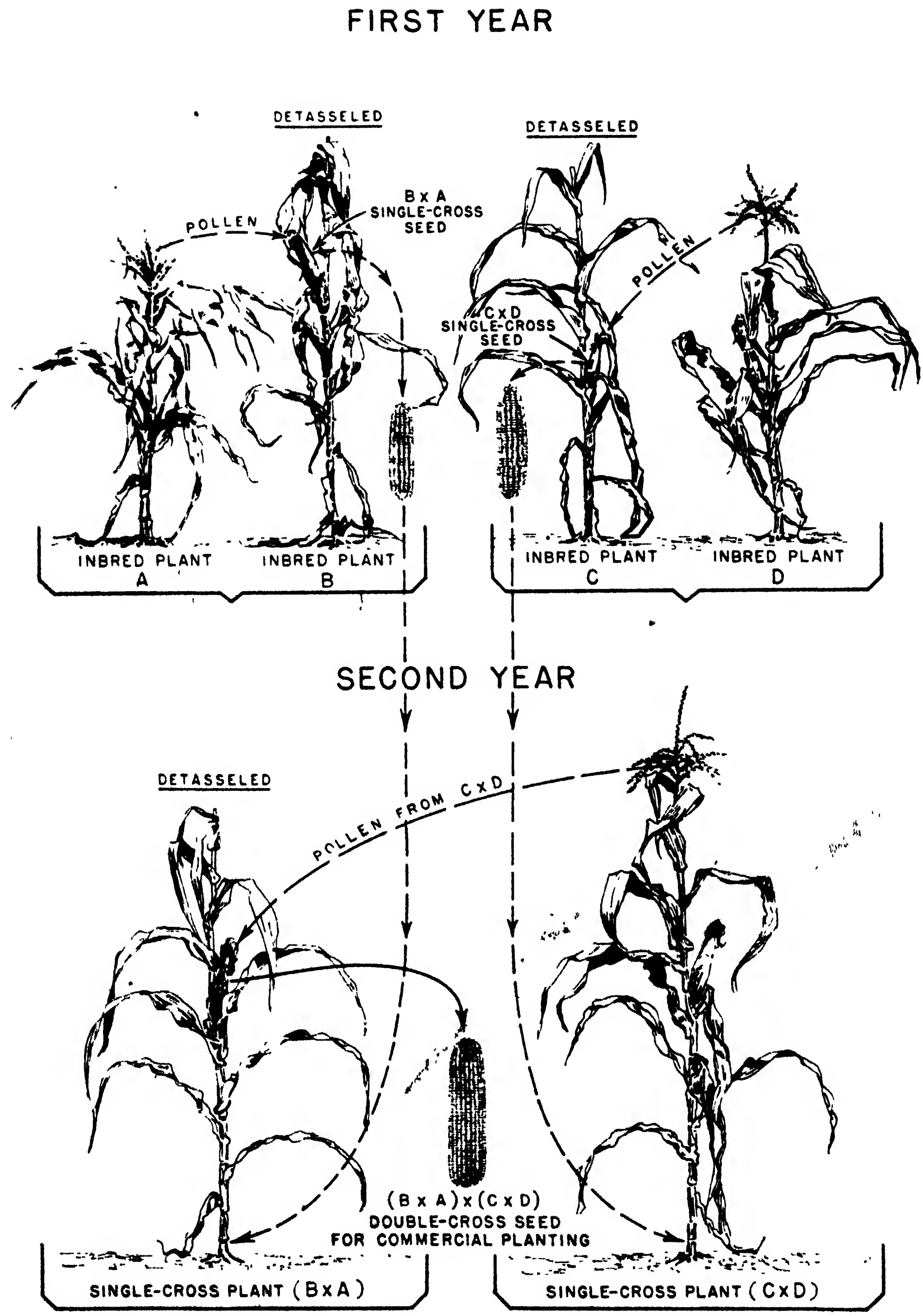


FIG. 4. Diagram of method of crossing inbred plants and of crossing the resulting single crosses to produce double-cross hybrid seed. *Farmers' Bulletin No. 1744. Courtesy U. S. Dept. Agr., Bur. Pl. Ind., Soils and Agr. Eng.*

represented in Figure 4 by a single ear. It is this seed that is planted to produce commercial corn.

Advantages of Different Hybrids

Any of these hybrids can be used in planting for commercial corn produc-

tion. The single cross is at a disadvantage because of the low yield of seed and its consequent high cost. Moreover, the irregular size and shape and the generally small kernels of present field-corn inbreds make the commercial utilization of single crosses impractical. Single crosses produce the most uniform plants and ears of any of the hybrids. They accordingly have special value when uniformity is most important. Thus uniformity is highly desirable in sweet corn for canning, and, to some extent, single crosses between inbred strains are being used commercially for this purpose. In field corn, however, three-way and double-cross hybrids will be used unless much better inbred strains are developed than are available at present.

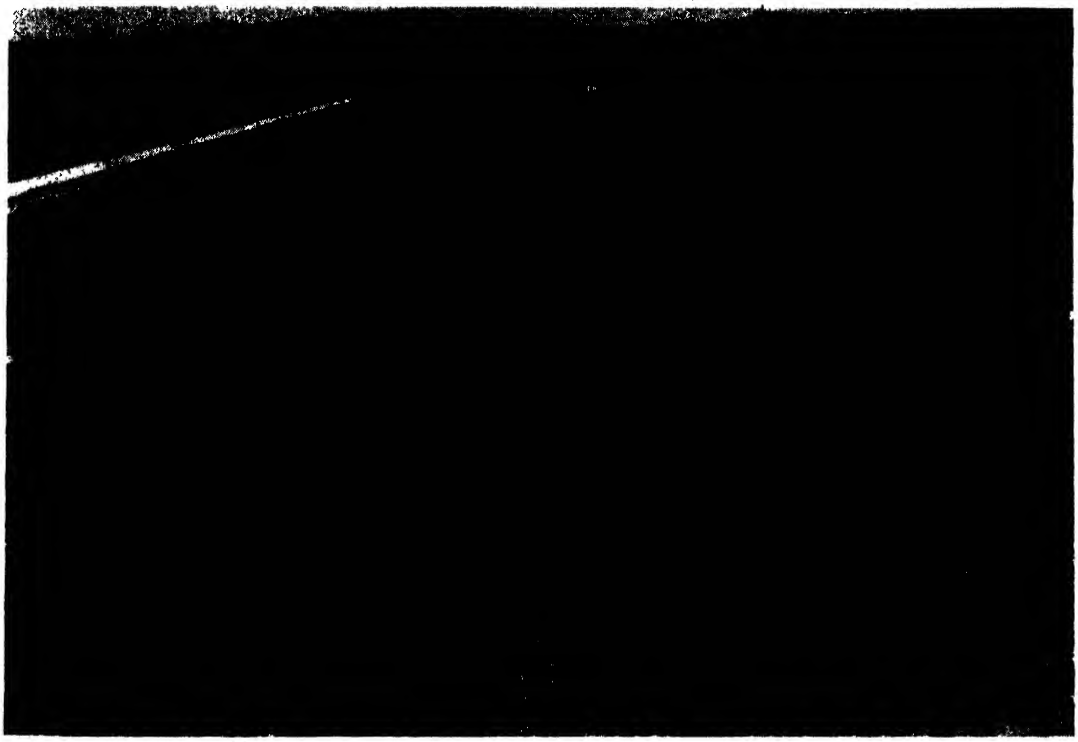
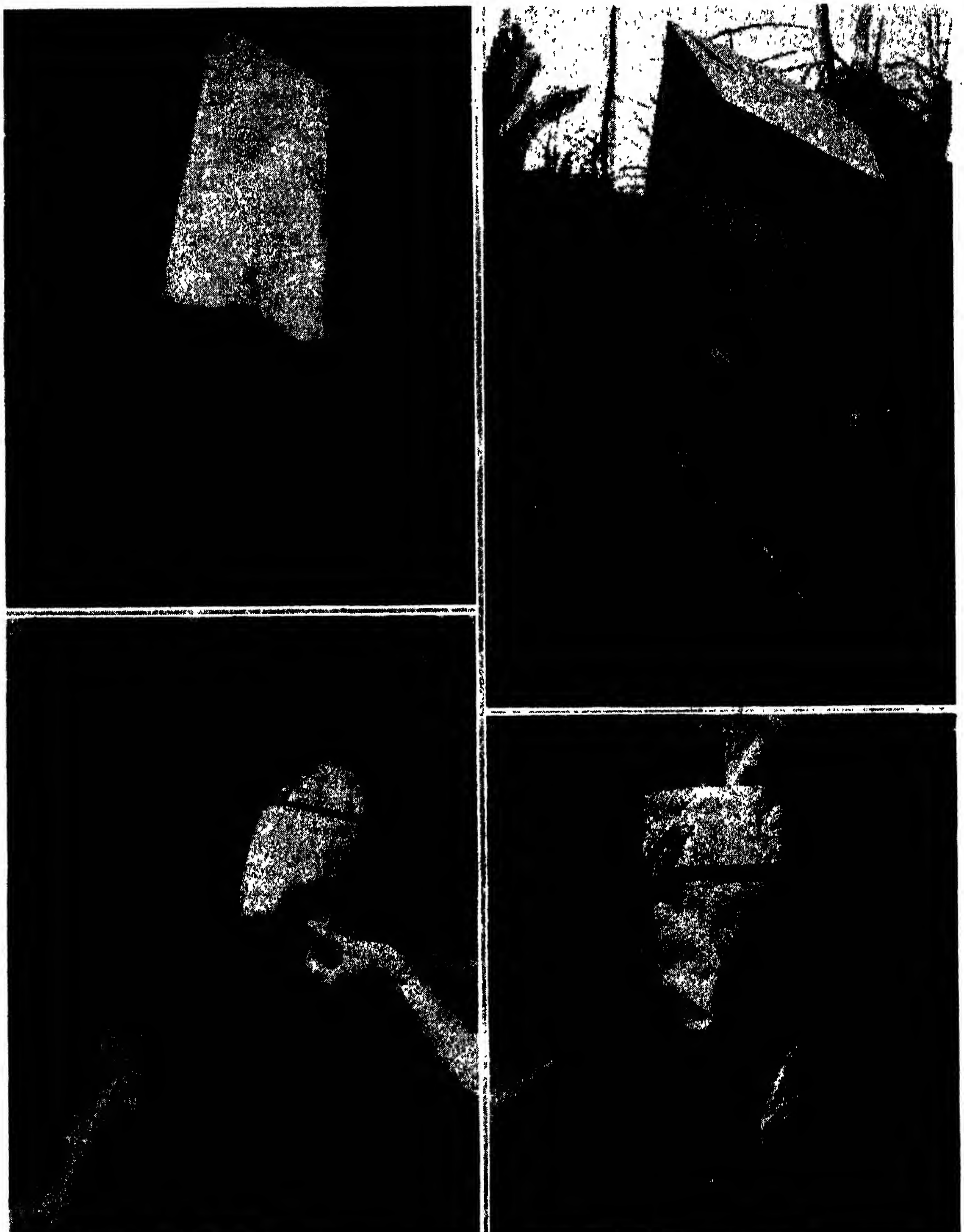


FIG. 5. A typical production field that will yield Hybrid Corn seed for growers' use. Note the tasseled rows that provide pollen for the larger number of detasseled rows from which Hybrid-Corn seed will be harvested for sale to corn farmers. *Photo courtesy Funk Bros. Seed Company, Bloomington, Illinois.*

The three-way cross has no particular advantage over the double cross. It is slightly more uniform but not importantly so. Probably the main reason for the production of three-way crosses commercially has been that it was easier to find three reasonably good inbred strains than four. Another advantage of the three-way over the four-way cross is that it requires fewer isolated plots. The serious disadvantage of the three-way cross is that an inbred strain must be relied upon to supply pollen for the cross. Unless an inbred that can be counted on for this purpose is available, the three-way cross is impractical. Even a reasonably good pollinating strain requires a somewhat larger proportion of male parent plants with a somewhat higher cost of seed production. For the present and for some time to come, therefore, the double cross seems to be the most practical source for hybrid seed corn.

The only value of top crosses of field



STAGES IN ARTIFICIAL SELF-POLLINATING OF CORN

FIG. 6. (*Upper left*). Paper bag being placed over staminate tassels preparatory to pollination.

FIG. 7 (*Upper right*). Paper bag fastened over staminate tassels.

FIG. 8 (*Lower left*). Paper bag being placed over ear shoot before the silks emerge.

FIG. 9 (*Lower right*). Paper bag fastened over the ear shoot.

STAGES IN ARTIFICIAL SELF-POLLINATING OF CORN

FIG. 10 (*Upper left*). Paper bag removed from ear shoot one day after Fig. 9, the silks grown out and being cut off, the decapitated shoot to be covered by a glassine bag.

FIG. 11 (*Upper right*). Silks grown out of decapitated shoot one day after Fig. 10 and visible through glassine bag.

FIG. 12 (*Lower left*). Glassine bag removed from ear shoot one day after Fig. 10, and emerged silks being pollinated from bag of Fig. 6.

FIG. 13 (*Lower right*). Paper bag placed over self-pollinated ear of Fig. 12. This completes the self-pollinating operation. *Photos 6–13—By courtesy of the Conn. Agr. Exp. Sta.*

corn for commercial use at present appears to be in the fact that it is easier to find one inbred that will combine well with some standard variety than to find three or four inbreds that will produce a good three-way or double cross. Experimentally, top crosses provide an efficient means for the preliminary testing of inbred strains for later use in other hybrid combinations.

The user of hybrids need not worry about whether he is getting single-cross, three-way cross, or double-cross hybrid seed, if it is of good quality (quality including size and shape suitable for machine planting) and if it has a definite record of productiveness in his community. The producer of hybrid seed will be governed largely by his individual facilities and the inbred strains that are available to him.

Producing Hybrid Seed Corn

Regardless of what kind of hybrid seed is involved, only the first generation of the hybrids should be sold or used for commercial planting. Only from this generation, *i.e.*, the seed that was actually cross-pollinated by another strain or hybrid, is the maximum benefit of hybrid vigor to be obtained. The second generation of any double-cross hybrid, that is, the seed produced by the first generation, may be expected to yield from about 10% to 25% less than the first generation, the exact decrease depending upon the particular hybrid. It is this fact that necessitates producing the hybrid anew for each season's use.

Hybrid seed is produced for commercial use by growing rows of the two parents in an isolated field and detasseling the plants of the female parent. In general, a field for this purpose should be not less than 40 rods from other corn unless there are buildings, trees, or other barriers between, or unless the two fields do not tassel at the same time. From two to four rows of the strain to become the female parent can be planted to every row of that which will be allowed to function as the male parent. If an inbred strain is to furnish pollen, it is safer to plant not more than two rows of the female parent. If a vigorous hybrid is to be the male parent, four rows of the female parent can alternate safely with one row of the pollen parent in the corn belt. As the seed comes only from the female-parent rows, this is a good reason for using a vigorous male parent.

Detasseling at Blossoming Time

During blossoming time the field is gone over at regular intervals, and all tassels are pulled from the female-parent plants before they shed pollen. With few exceptions the tassels emerge enough so that they can be seen before they begin to shed. A quick upward pull at this time takes the tassel out cleanly without damage to the plant. Tassels pulled too early are likely to bring with them part of the top of the plant, with some damage. On the other hand, it is not safe to wait too long lest the tassels begin to shed before they are pulled. Therefore, it is necessary to go over the field practically every day until detasseling is completed.

Material Value of Hybrid Corn

The hybrid corn technique devised incidentally at an extremely modest cost at a research station devoted to experimental study of evolution has made modern corn breeding a highly specialized science. State and federal experiment stations pursue various courses in seed-breeding aid of the corn-growing industry. Large hybrid corn companies are, however, becoming more and more self-reliant with large staffs of highly trained specialists capable of meeting within natural limitations the seed requirements of the gargantuan corn-growing industry.

Corn hybrids are tailor-made to meet cultural and industrial requirements.

Field implements and processing plants are designed for most efficient planting, harvesting, curing and grading. Truly, American corn-growing, with still greater advances in view, has already reached a peak of efficiency undreamed of in the earlier life of many of us who enjoy the tremendous benefits of the marvelous commodity Hybrid Corn.

The percentage of total corn acreage planted with Hybrid Corn in the United States between 1933 and 1944 increased from 0.1% in 1933 to more than 50% in 1943, and the acreage continues to increase yearly. By 1946 some of the most important corn-growing areas had increased their acreage of Hybrid Corn to almost their entire crop.

Following the harvest of 1943, M. A. McCall of the United States Department of Agriculture said in commenting upon the use of Hybrid Corn seed: "Never until the last two years has the United States grown more than 3,000,000,000 bushels of corn in each of two successive years, and never before on as small an acreage. This is almost certain to stimulate even wider use of intensive methods with other crops".

Mr. McCall went on to say that on the basis of hybrid corn acreages and yield during the preceding six years and the average yields during 1923–32 (the last normal 10-year period before Hybrid Corn came in), it can be estimated that Hybrid Corn added 629,000,000 bushels of corn to our total crop in 1942, and 669,000,000 bushels in 1943. This is equivalent to adding each year almost one-fourth of a normal crop of corn in years before Hybrid Corn came into use.

Hybrid Corn Justifies Research in Pure Sciences

The tremendous success of Hybrid Corn in terms of practical gains derived from research in pure science has served toward encouragement of research in related and unrelated fields. Corn has been the object of intensive genetic research in well-staffed and well-equipped laboratories whose findings have advanced greatly our knowledge of plant genetics.

Important progress has already been made in achieving and utilizing hybrid vigor similarly in other kinds of plants. Hybrid livestock and poultry are being studied and some have demonstrated remarkable superiority over parent breeds.

In calling attention to the importance of adequate national support of scientific research, Dr. L. J. Stadler of the University of Missouri said, in part, while testifying before a sub-committee of the Committee of Military Affairs of the United States Senate on the subject of Science Legislation:

> We know from the crop estimates of the United States Department of Agriculture what fraction of the corn planted in each county was planted from hybrid seed, and we know from numerous and widely distributed field experiments the comparative performance of different strains of corn when grown side by side under identical conditions. In these experiments adapted hybrids consistently outyield the varieties of corn formerly grown, with an average margin of over 25 percent.
>
> This is an increase in yield which costs nothing except the added cost of producing the special type of seed and the added cost of harvesting a larger crop. In practice the seed is commonly produced by specialized seed growers, and the production and sale of hybrid seed corn has now become an industry with an annual turnover of about $75,000,000.
>
> A conservative estimate of the increase in national corn production during the four years 1942–45, due to the partial use of hybrid corn is 1,800,000,000 bushels. The money value of this increase on the basis of farm prices per bushel is more than $2,000,000,000.
>
> It is, therefore, no exaggeration to say, speaking in terms of the overall national economy, that the dividend on our research investment in hybrid corn, during the war years alone, was enough to pay the money cost of the development of the atomic bomb.

Manioc—*A Tropical Staff of Life*

A plant which in one form contains deadly prussic acid and in other forms nourishes thousands of primitive people and furnishes tapioca to modern man.

ROBERT W. SCHERY
Missouri Botanical Garden

Importance, Preparation, Use

PERHAPS it's a grain? No. A potato or bean? Certainly not. Well then, what other form of vegetable life may be so linked with man's daily existence as to be termed a "staff-of-life", to bear the burden of furnishing the basic food in the diet of many millions of men? Dwellers in the tropics—in the Americas from Mexico south to Paraguay—many of whom would scarcely recognize a potato and whose only acquaintanceship with important cereal grains is an occasional planting of maize, can tell you. It is manioc, the tuberous root of *Manihot esculenta* Crantz (*M. utilissima* Pohl.). Yes, manioc, or mandioc, or cassava, or yuca, or any of several other Indian- or Spanish-sounding titles, is the name of the most important—and frequently the only—primary source of sustenance to thousands of interior-dwelling Latin Americans and to their tropical brethren of even more distant lands. Surprising this may seem to North Americans, for most of us have never seen manioc nor even become familiar with its name, and little detail concerning it has been published north of the Spanish-speaking republics. Yet, unknowingly, most of us have eaten it, in a specially prepared form, as tapioca.

Amongst the Latin countries to our south manioc is known in an endless selection of varieties, many of which are poisonous to varying degree, for the manioc species contains a poisonous glucoside related to prussic acid. Selection of "sweeter" varieties, those graced with less of the toxic glucoside, permits of more ready preparation than do the "bitter" maniocs, although I know of none that is not cooked or otherwise made edible by man's hand. No hard and fast boundary exists between "sweet" and "bitter" maniocs, all stages of intermediacy being found. Quite probably growing conditions—soils, rainfall, elevation, and the like—are as important in determining the poisonous character of a manioc as are the vague hereditary factors of varietal differentiation, or even more so. Basically two methods are followed to make palatable this essentially non-edible raw root. The simplest—one often used for sweet maniocs—consists of mere boiling in water as we might boil potatoes or sweet corn. Such boiling drives off or changes to inocuous form the small quantities of prussic acid or glucosidal poisons, just as would fermentation or extraction by mechanical means. A sticky, starchy, fibrous vegetable results, with a consistency as "heavy" as incompletely cooked macaroni. It retains its natural shape, much that of a very slender sweet potato. As such it is consumed, a staple item of the diet in outlying areas of southern Brazil, Paraguay and the Andean countries northward.

But in northern and eastern Brazil, as perhaps elsewhere, the second and more elaborate mode of treatment gives

a readily handled staple, sacked and sold much as is our wheat flour. There "farinha",[1] the final pulverized form of manioc, is the cheapest, omnipresent, and frequently the sole food for scores upon scores of native peoples—peoples generally inadequately fed, to be sure, from the dietary standpoint. I have encountered distant interior villages where the only food to be purchased was farinha. This dry form, plus whatever windfalls in the way of wild game might befall the villagers, was the complete diet in the village at the time.

Farinha in northeastern Brazil is made by first rasping the tuberous manioc roots in primitive local "mills". A horse or oxen yoked to a rotating beam continuously circles the hand-fashioned wooden gear, supplying power. A series of gears or pulley-belts ultimately rotates a wooden roller at high speed. Studs of nails, driven firmly into the roller on various planes, whir threateningly as an outer blur to the roller. The manioc root is pushed against the whirring spikes, and is shredded to bits by the whirling studs, much as excelsior might be torn from soft woods. The mushy mass of shredded manioc is then carried to a crude press, generally consisting of a wooden box with plunger. The plunger is forced against the box by a lever weighted with stones, or by a

FIG. 1. Young plants of manioc or cassava, *Manihot esculenta*, the source of farinha and tapioca and used industrially in laundry and sizing starches, adhesives, simple sugars, syrup, alcohol, acetone and animal fodder. (*Courtesy of the New York Botanical Garden.*)

[1] A Portuguese word, pronounced fah-reén-yah, meaning "flour."

gigantic wooden screw, itself tightened through human sweat in lands where a blistering tropic midday drives all creatures to the shelter of shade. This pressing expels liquid from the mass, including most of any poisonous principles. Sometimes the shredded manioc is merely drained in basket-like sieves, where specially designed presses are not to be had. Farinha from such drained manioc is just as palatable as that more conveniently made after expression, for in final drying any poison, like water, is completely expelled. I have not seen the

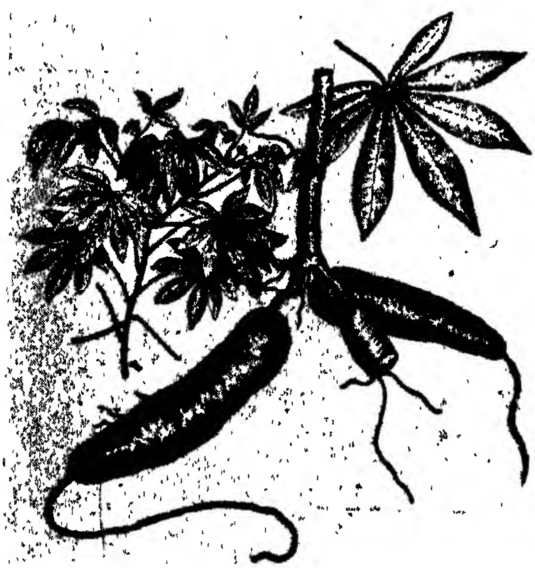


FIG. 2. Foliage and tubers of manioc. (*From L. H. Bailey, Cyclopedia of American Horticulture. By permission of The Macmillan Company, Publishers.*)

expressed liquids retained for fermentation—to make, strangely enough, a drink poisonous only as is its alcohol—as is the custom in regions to the west. The manioc mass is finally spread on flat tins, above a wood or charcoal fire, where it is turned and stirred until dry, a process similar to that followed in making tapioca. The result is farinha, coarser than our wheat flour, resembling somewhat North American cornmeal. This is the staff-of-life in thousands of unnamed out-of-the-way places.

In some localities, usually mixed Indian communities near Amazon country, an interesting method of expelling the manioc juices was developed. The tuberous roots, after proper soaking and cleaning, are cut or shredded by hand and then dumped into a gigantic cylindrical "chinese finger-lock" woven from palms or other fibrous material. This six-foot tubular "finger-lock" operates the same as do the novelties known to many Americans: pulling or stretching lengthwise alters the position of the fibers, narrowing the tube and gripping its contents ever more firmly. The tube with its manioc content is hung from a suitable support, and tension is applied at the base by simple leverage, created from a pole and human endeavor. The narrowing of the tube squeezes out the juices from the contained manioc—juices often collected and saved for purposes previously hinted. Those same juices, concentrated through boiling, form West Indian pepperpot, an ingredient of our better known meat sauces. In other localities special grating boards have been devised, solely for shredding manioc. Story has it that white man first discovered diamonds in the Guianas in a native manioc grating board.

All these manioc foods are to me rather tasteless, being almost exclusively of a starchy nature. In South America boiled manioc is usually eaten along with beans, rice and maize, if and as they are available—usually seldom in poor interior villages. Salted and in combination with other foods it is not unpalatable. Farinha is customarily eaten dry, except where resource permits its preparation as a delicacy in the juices or grease of grilled meats, usually with an onion seasoning. I find it quite palatable, both in the latter way, and in the former if some sort of sauce, gravy or broth is available. Eaten dry, by the handful—the common way in less affluent families—one can not anticipate

much gustatory pleasure. But in a land where farinha is usually available at but a few cents per pound, families of the interior, living on less than 25 cents per day, can afford little else.

Botany

Manioc is a small shrub of the *Manihot* genus, an immense genus which includes several rubber-producing species of significant economic importance. In Brazil alone, literally hundreds of species of *Manihot* are known. That most described species and varieties are "good" is doubtful. I have seen marked variability and apparent hybridization in several well recognized rubber-producing species. Similarly, hundreds of varieties of edible maniocs, mostly of the *Manihot esculenta* species, have been recorded, from Paraguay to Colombia in South America, from Jamaica and the West Indies, from East Africa, India, Ceylon, Madagascar, the Philippines, and even from Florida. Few of these have been preserved for herbaria, and little comprehensive study has compared or related varieties of one area with those of another. Most of these varieties have undoubtedly arisen since manioc has been under cultivation, and many are only locally recognized

A member of the spurge family, manioc is a relative of the spine-studded, stinging jatrophas, the common poinsettia, and the Pará rubber tree—all producing a milky juice or latex. Manioc itself much resembles its lactiferous brethren of *Manihot*, but is only slightly or scarcely milky. Its palmately lobed leaves are like those of its relative, the castor bean, and are quite variable. Its flowers, typical of the Euphorbiaceae, may be deficient in either male or female elements. It seems to be quite tolerant of soil types, is able to endure nearly complete neglect, and thrives relatively free from disease or insect pests.

Among all the Euphorbiaceae, only *Manihot esculenta,* along with one or two other species, produces the tuberous roots which make it important the world over. These roots vary from variety to variety, from place to place and from time to time. Young roots harvested about six months from planting are reported to contain up to 6% sucrose as well as the normally high percentage of starch. Older roots, up to about 18 months from planting, give optimum yields and abundant starch. Such roots frequently consist of 30% or more starch by weight. Very old roots become more or less lignified and unsuitable for ordinary food or commercial purposes. In all roots the epidermal and cortical regions seem to contain most of the poisonous glucosidal or prussic acid principles. The pithy center, relatively free of these poisonous elements, contains most of the starch. Thus in preparation of commercial starch, peeling or fermenting off the outer layers, as is commonly done, little diminishes the yield of starch and at the same time permits a purer dirt-free commercial product.

Cultivation

Manioc is typically propagated by stem cuttings, a process the simplicity and ease of which appeals to the not overly ambitious tropical peoples, whose agricultural work must be done by sweat of the brow during tedious hours in the field. Moreover, stock for cuttings always grows available, and no planting rush need disturb the tropical tranquility; what isn't planted today. . . . Planting methods in the interior are those of generations past. In northeastern Brazil forest is burned during the dry season, and then before the life-giving rains come, sections of manioc stem are planted in the burnt-over area. Crude cultivation with heavy iron hoes may follow as needed, or sometimes the manioc may be left to fare for itself. In as little as six months under good

growing conditions a harvest may be obtainable. Plants with their roots are torn or dug from the ground. Roots destined for the farinha mill are cleaned and peeled prior to being shredded. Others may be stored in piles, or even left in the ground until needed. One of the great assets of manioc as a food and commercial plant is its remarkable keeping quality. And yields may be as high as 20 tons to the acre, while plants may be grown as close as a yard apart (10,000 to the hectare).

Native to the Americas, possibly originating in Brazil, manioc is unknown in the undomesticated state. Its ancestral form, from which it was first cultivated by primitive man in some ancient bygone era, is not known. Yet modern man, in the form of the sixteenth-century Portuguese explorer, finding manioc cultivated by Brazilian Indians, realized its worth and soon carried it to tropical Africa. Thereafter manioc spread throughout the world tropics, especially by the hand of British and Dutch colonizers, to become a food of primary importance in all tropical lands meeting its rather exacting temperature requirements. And today, perhaps, both Africa and the Dutch East Indies surpass South America in production of this food-gift from the Western World, an original gift supplemented by subsequent introductions of newer varieties.

Modern Industrial Uses

Manioc is of importance not alone for its value as local food, but also as a tropical export item to Europe and North America. In these latter continents it is sought for preparing food, and laundry and sizing starches; for making glue and postage stamp adhesives; as a source of simple sugars, syrup, alcohol and acetone; as animal fodder; and for human consumption as tapioca or products of manioc flour.

In preparing industrial starches, the chief non-nutritional use for manioc, the "tubers" are treated in the early stages much as in the making of farinha. By various means the thoroughly cleaned and washed roots are shredded or crushed, during which operation individual cells are broken apart. Only by such breaking of the cells can the minute starch grains contained within escape. After straining fibrous material from the crushed mass, the remainder is streamed in water to appropriate settling basins. Settling usually serves to separate the starch grains from the watery medium, after which the supernatant liquor is decanted off. The starch sediment is then dried, following additional washings if needed. Manioc starch has been reported highly desirable for sizing cotton thread prior to weaving, being more pliable and infiltrating the thread better than does corn starch.

Stirring or shaking manioc starch on a heated plate at controlled temperature until the starch swells and masses into pellets of the proper size, produces the common tapioca of commerce. The starch is partially converted to sugar during the process, as well as rendered somewhat gelatinous. Starch for various other food purposes is often known in the trade as "arrowroot", and is said to be especially digestible. Mention has already been made of "pepper-pot" meat sauces, prepared from boiling down expressed manioc juices from which starch has been removed, and to which are added flavorings and pepper. Any poisonous elements originally contained are rendered innocuous by repeated boilings. Boiling down juices from particularly sugary varieties produces a molasses-like substance, said to be highly esteemed in Paraguay.

Manioc may also serve as a source of alcohol, primitively produced among aborigines by allowing the expressed juices to ferment. Some of the most colorful tribal customs involve drink-

ing alcoholic beverages produced from manioc, the juice of which is frequently obtained by mastication and expectoration. More modern methods of hydrolizing starches of the starch-rich manioc root to sugars for subsequent fermentation would produce more certain industrial results and complementary higher yields of alcohol.

Raw manioc roots, or manioc wastes after expression or starch removal, are usable as cattle feed. Given alone, such feed leads to dietary unbalance in the animals, lacking, as it does, needed protein elements. But being low in protein, manioc is thought by many to drain the soil less severely of nitrogenous materials than do many other crops used for cattle feeding. Grown in conjunction with proper leguminous forage, dietary balance for cattle should be attained, while the soil could likewise be expected to benefit from growth of the legume.

Thus this starch-rich food-for-millions (manioc produces more utilizable starch per acre than any other known crop), a true "staff-of-life" amongst many ill-nourished tropical populations, also helps in its minor way to nourish the economy of temperate latitudes.

Utilization Abstracts

More Antibiotics. Recent investigations indicate that wild American ginger, formerly grown for its cathartic and emetic qualities, possesses two antibiotics, one of which is more active than the other and effective "against pus-forming gram-positive bacteria such as staphylococcus, streptococcus and pneumococcus, but has no effect on germs in the intestines". Burdock and garlic also seem to have promise as medicinals, and in 1921 Japanese scientists isolated a substance, protonanemonin, from buttercups, "which was found to be a potent antibiotic, but too toxic for human use". (*Anon., Chemurgic Digest 5(13): 231. 1946*).

Oil of Rue. A little-used though nevertheless commercially produced vegetable oil is that of the genus *Ruta*. Small quantities are employed in flavoring materials and in certain types of perfumes and soap scents. The oil is obtained by distillation from several wild species in Spain, North Africa (mainly Algeria), Sicily, Sardinia and France (mainly Provence). The principal producing regions are the Provinces Badajos, Cádiz, Seville, Cordoba and Huelva in Spain. Wild plants are collected in July and August during the blooming period and distilled in field stills without previous drying. The pollen of the plants causes skin blisters on susceptible workers. During recent years Spain produced from two to twelve tons of rue oil annually. (*E. Guenther, Am. Perf. & Ess. Oil Rev., May, 1946*).

Vegetable Oil Exports from Brazil. Vegetable oil exports from Brazil in 1945 amounted to 43,264 tons as compared with 34,668 tons in 1944, surpassed only by the figures of 1941. More than 90% of the oils came to the United States, consisting of cottonseed oil, oiticica oil, castor oil, coconut oil, babassu oil and others of less importance. (*Anon., Brazilian Bulletin, Brazilian Gov't Trade Bur. 3(62): 1. 1946*).

Mulberry Trees in Brazil. The silk industry in the State of Sao Paulo, Brazil, has increased the planting of mulberry trees, used for raising the silk-worms, from 15 million in 1941 to more than 250 million in 1946. (*Anon., Brazilian Bulletin, Brazilian Gov't Trade Bur. 3(62): 5. 1946*).

Barley. "Classification of barley varieties grown in the United States and Canada in 1945" is the title of Technical Bulletin No. 907 of the U. S. Dept. of Agr., issued in May, 1946. It contains 190 pages, 93 figures, and deals with the morphology and taxonomy of 140 varieties of barley. (*E. Åberg and G. A. Wiebe*).

The Cork-Oak Tree in California

WOODBRIDGE METCALF
Extension Forester, University of California

There are 5,000 trees in various parts of the State, planted at various times, and recent experimental strippings of the largest have yielded 600 to 1,000 pounds of high quality cork per tree. Does this presage an American cork industry?

Historical

THE cork oak tree, *Quercus Suber* L. is native in the vicinity of the Mediterranean Sea where it is a prominent feature of the vegetation in about five million acres of natural forest situated in Portugal, Spain, Italy, North Africa, Greece and the Mediterranean islands. Like the other evergreen oaks, it is quite variable in leaf, flower and acorn characteristics, and some authorities have separated out one variety known as *Q. occidentalis,* for which the identifying characteristics are too obscure for exact determination under American conditions. Holm oak, *Q. Ilex* L., is usually associated with cork oak throughout these natural forest stands, both trees having sturdy trunks, heavy spreading branches and broadly rounded crowns of dense, holly-like foliage, similar to that of the coast live oak, *Q. agrifolia* Née, and highland live oak, *Q. Wislizenii* DC., of California foothills.

The outer bark of cork oak, known commercially as "Corkwood," has been harvested from these Mediterranean forests for many years without injury to the trees which can be stripped at about ten-year intervals until well over one hundred years old. The highest grade corks for wine bottle stoppers are made from third to sixth stripping sheets of cork from trees 50 to 80 years old, as this cork has the minimum volume of lenticellular pore spaces in it and is, therefore, of very uniform quality. During the past quarter century cork has gradually increased in industrial importance because of its qualities of lightness, resilience under pressure, imperviousness to liquids and gases, even in composition form, and its remarkable resistance to the passage of heat, which has given it a position of primary importance in the insulation field.

These with many military and naval uses have resulted in steadily increased demands for cork until the world output is now said to be in excess of three hundred thousand tons per year, of which between 50% and 60% is used in the United States. This demand is now at the rate of one ton for each 17 acres of natural cork oak forest and may be approaching the maximum possible continuous output from these stands. This is based on a conservative estimate of an annual yield of 200 pounds of cork per acre of well managed cork forest on good soil in the better parts of its natural range. It is thus evident that the United States is using the entire output of cork from 1½ to 2 million acres of forest, all of which is across a wide ocean from our shores. During World War II cork was a material of critical military importance, and the supply had to be carefully rationed. Thus an emergency supply of this material on trees growing within the limits of this continent may be of very great importance in a future

emergency. The cooperative cork oak program which has been under way in California since 1940, has in view the creation of such an emergency supply.

The University of California, California State Division of Forestry, California Forest and Range Experiment Station, and the Western Crown Cork and Seal Corporation have jointly sponsored this project and proceeded along the following lines:

1. Listing of all cork oak trees and plantations in California as a basis for collection of sufficient acorns to carry on the growing of trees and the determination of the quality of cork produced by California trees.

2. Collection of acorns for propagation and free distribution of from 20,000 to 30,000 cork oak trees per year; with tests for storage, germination, nursery and planting technique to give the best results; and shipment of acorns as required to start the program in other states.

3. Stripping of sufficient trees of various sizes throughout the state to determine amount and quality of California grown cork, feasible stripping dates and tools and methods of carrying on the work with minimum damage to the trees, many of which were privately owned and prized as ornamentals.

4. Determination of geographical and altitudinal limits within which the cork oak may be successfully grown with moderate attention and irrigation.

5. Observations on insects and diseases affecting cork oaks in California.

6. Genetic studies on different races of cork oak and selection of the more desirable strains for high production and good quality. Tests of possibility of hybridizing *Q. Suber* with *Q. variabilis* Blume and perhaps other species of oaks.

7. Check on the possibility of growing Amur Velvet, *Phellodendron amurense* Rupr., Formosa cork, *Quercus variabilis*, and any other cork-producing trees in this region.

After six years of work we can now report satisfactory progress along most of the lines indicated above.

Records of Cork Trees Growing in California

Some preliminary studies of cork oaks growing in California were made by the writer in 1929 and recorded in a publication issued that year at the request of the Sacramento Region Citizen's Council.[1] With this as a beginning and with the assistance of a number of interested agencies and individuals, it has been possible to record the location and size of approximately 5,000 cork oak trees of moderate to large size which are growing in some 30 California counties. About 2,000 of these are in Los Angeles County, and special thanks are due to Mr. Averill Barton of the Los Angeles County Forestry Department for the very complete record he compiled of all such trees growing in county territory during 1941. With this and similar records which are being kept in a card file, it has been possible to contact owners of trees to arrange for collection of acorns and test stripping of cork where they did not object to having this done.

An interesting feature of these records of early plantings is the fact that no trees were found to have been planted during the Spanish period. Many of the oldest trees apparently go back to the shipment of acorns brought in to San Francisco by the Patent Office in 1858, though there is a possibility that the large trees on the J. T. Kiser Ranch, south of the town of Sonoma, may have been planted three or four years earlier. It seems probable that the Spaniards attempted to bring in the cork oak along with the olive, grape and other things they started here; but from what we now

[1] "Cork Oak—A Forest Tree With Possibilities for California". Reprint from October 1929 Bulletin of the State Department of Agriculture. Reprint from State Printing Office, Sacramento, 1929, by Woodbridge Metcalf.

know of the storage requirements of cork oak acorns, these apparently died during the long, slow voyage necessary in the period prior to 1850. When transportation was speeded up with the introduction of clipper ships more of the acorns came through in viable condition. It seems fairly certain that the Kiser Ranch trees, which are now between 45 and 50 inches in diameter, were planted in the 50's, and that the three fine, tall cork oaks at Tuttletown, Tuolumne County, grew from the above shipment of acorns, as they are reported to have been planted in 1858. The tree at Clarke's Nursery, Santa Clara County, may have been from this same lot of acorns but is much smaller than the other trees. Some trees evidently go back to the 60's and 70's, and the tree at the old mining town of Todd's Valley near Forest Hill, Placer County, may be one of these. It has made good growth under natural conditions at 2,700 feet elevation but is said never to have produced a crop of acorns. It is locally reported that A. G. Read, storekeeper at Todd's valley for many years, got cork oak acorns from France in 1870 and that the tree grew from one of these. It was 39 inches d.b.h., 50 feet tall and 70 feet across the crown in 1942, and produced cork of good, firm quality. It is growing at a higher elevation than any other tree in California. There are well developed trees of cork growing along the coast from San Diego County (Balboa Park) to the most northerly tree which is old but quite misshapen and grows on a moist flat near Rhonerville, Humboldt County. It has never produced a crop of acorns. In the interior valleys there are good specimens from Riverside County on the south to Butte County on the north.

FIG. 1. One of the four large cork oak trees on the Kiser Ranch, Sonoma County. Diameter breast high: 50.2 inches; yield of cork when stripped to a height of 14 feet in 1942: 650 pounds.

There are a number of fine cork oak trees in Santa Barbara, the largest of

which is reported to have been planted from an acorn brought to Santa Barbara by a man named Hinchman in 1857 and planted by Captain H. G. Trussell at 412 West Montecito Street. An article in the "News Press" stated that in 1875 this tree measured nine inches in diameter. This tree stood on an irrigated lawn, and in 1942 when over 80 years old it was 33 inches in diameter, thin in the crown and evidently suffering from some root trouble which apparently caused its death during 1945. A tree of similar size and age, but more vigorous and with thicker cork, is growing on the Sexton property in Goleta. It measured 29.17 inches d.b.h. in September, 1942.

The largest cork oak tree in California is growing near the main building of Napa State Hospital at Imola, Napa County. It is reported to have been planted in 1871, and at 73 years of age had a diameter of 58.2 inches, a height of 75 feet and a crown spread of about 100 feet. It grows on an irrigated lawn and in recent years has produced several large crops of acorns.

During the 80's there was evidently an increase in cork oak plantings, as a number of nurseries had seedlings for sale. By this time acorns grown in California were evidently produced in moderate quantity, but not many records of planting are available. The annual reports of the Agricultural Experiment Station of the University of California state that between 1886 and 1891 a total of 803 cork oak seedlings were distributed to land owners throughout the state. No record of the results of these plantings is available, but it is probable that several of the fine trees on farms in the Sacramento and San Joaquin Valleys resulted from these plantings. The well developed trees at the McGill (Doak) Ranch near Oakville, Napa County, were set out on a rocky, rolling hillside from acorns which the owner, John Benson, is reported to have sent home from Spain. The fine trees at the R. E. Fields place near Biggs, Butte County, are reported to have been planted by John Rock, President of the California Nursery Company, about 1889.

After the U. S. Forest Service was established in 1905, considerable quantities of cork oak acorns were imported and planted on the three southern forests by the seed spot method. The acorns were evidently too old and dry, for germination was very low. The few which did grow are reported to have died from drought or were destroyed by gophers. The outstanding plantation of this period was set out by the University of California in 1904 at the Chico Forestry Station in Butte County. It occupies about two acres of gravelly soil of rather poor quality, the spacing was six by six feet and the trees were cultivated for two or three years after planting, but it is believed that they were not irrigated. No thinning was done until after 1940, but undoubtedly gophers took out many of the trees during the first decade; thus the trees made slow growth because of severe competition. When 21 years of age this plantation showed 383 trees per acre; the average diameter was 5.5 inches breast high and the average height 24 feet. The largest tree was 14.6 inches d.b.h. and 39 feet tall. When stripping experiments were started in this grove in 1940, the trees were 36 years old, and 166 of them were eight inches or over in diameter breast high, averaging 11 inches d.b.h. The largest trees are at the north end of the grove where the soil is somewhat better and there is probably some subirrigation from Chico Creek. This area, now within Bidwell Park, is the natural site for valley oak, *Quercus lobata* Née, and many fine specimen trees are in the vicinity of the cork oak grove. Several rows of seed spots, using acorns from the Maher cork oak at Campo Seco, were set out on the northeast side of this grove in 1917, followed by cultivation

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but no irrigation. In spite of some damage by gophers this seeding was quite successful, and a number of the resulting trees were large enough to be stripped of cork in 1943 and 1944. The largest had diameters of eight to ten inches at 26 years of age.

During the years from about 1910 to 1915 the Los Angeles County Forestry Department grew a considerable number of cork oaks each year and planted them along several county highways. The fine trees along Devonshire Boulevard in the San Fernando Valley were set out in 1915 and have developed into large and beautiful trees. With plenty of room to develop and with irrigated crops in adjacent fields supplying them some moisture, they averaged 20 inches d.b.h. and 35 to 40 feet in height when 26 years old. Other plantings of these years have grown more slowly when on poorer soil or under drier conditions, and some of them show quite severe infestation by the gall wasp insect. The fine planting of trees along the State Highway east of Davis, Yolo County, was set out about this same time and the trees have made similarly rapid and satisfactory growth with irrigated crops in adjacent fields and their roots in good Yolo sandy loam soil. Other fine rows of cork oaks along streets and highways in Riverside, Fresno, Kern, Sacramento and Placer counties show that the cork oak grows into a beautiful and satisfactory highway tree, par-

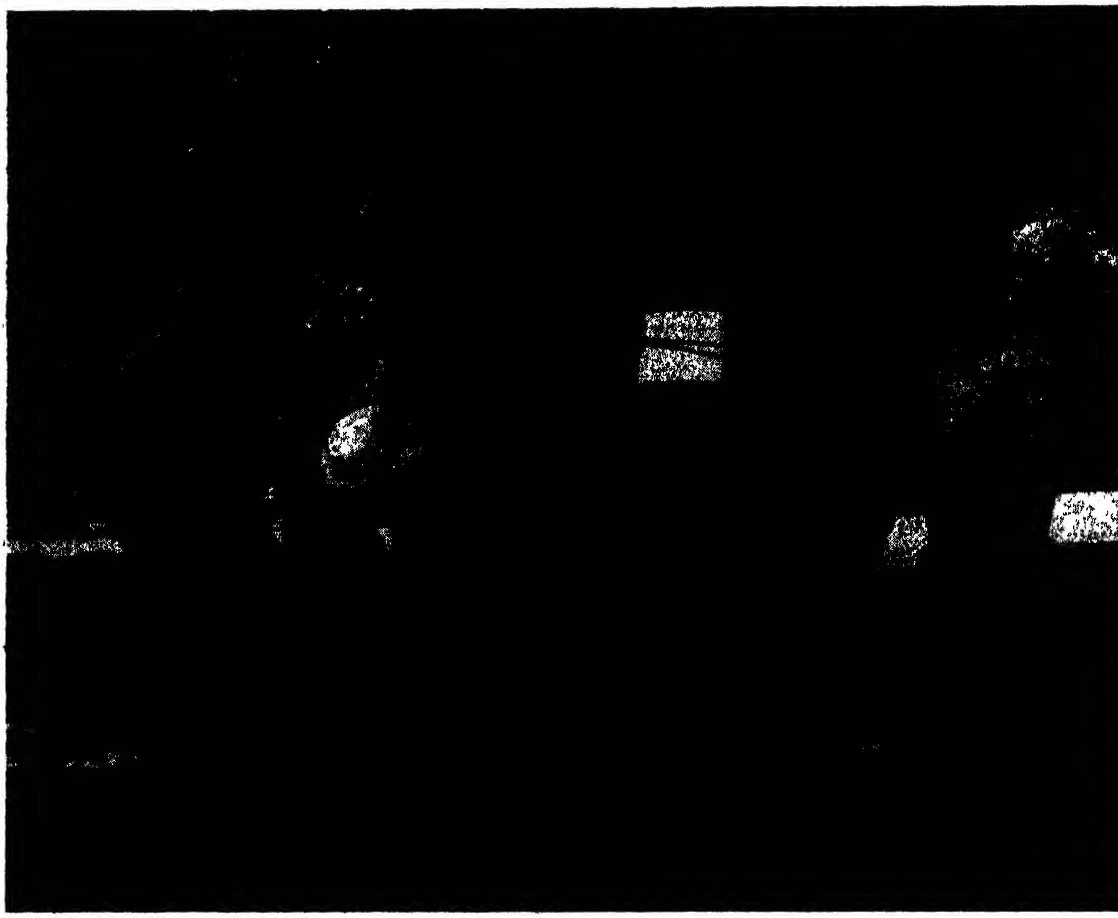

FIG. 2. Using the convex saw to make the vertical cut through the 58-inch cork oak at Napa State Hospital, July 27, 1943. Yield of cork when stripped to a height of 17 feet: 1,050 pounds. The tree is forming a good growth of new cork since the stripping.

ticularly where it receives some water from adjacent irrigated crops. It must, however, be pruned at intervals during the first 20 years in order to induce development of a clean straight trunk to a height of 10 to 12 feet.

From about 1890 on, it appears that commercial nurseries in California grew and sold cork oak trees in considerable quantities. They are listed in many catalogs, and Mr. Theodore Payne of Los Angeles promoted their planting for a number of years, particularly in 1916 when his catalog carried a fine illustration and description of a cork oak on the back cover. During these years also Mr. Emery Smith of San Francisco was a consistent advocate of cork oak planting in California. He included a display of cork stripped from trees at the James Lick property at Agnew among the exhibits of California products at the Chicago World's Fair, and though his main interest was along engineering lines, he never ceased to enthusiastically promote the planting of these trees.

The State Division of Forestry Nursery at Davis has long been a factor in the growing and planting of cork oaks, particularly on school grounds, along highways and on the grounds of state and county institutions. The records from 1930 to 1940 show a distribution of 74 lots of cork oaks in gallon cans during this period—a total of 2,864 trees before the start of the cooperative project in 1940.

Collection, Storage and Shipment of Acorns

Beginning with the crop of 1940 an effort has been made to secure a large volume of acorns each year for the growing of between 20,000 and 30,000 trees annually in California and to comply with requests from southern and southwestern states in order that they might propagate and distribute cork oaks for trial planting within their borders. By setting a price of ten cents per pound, and by urging 4-H Clubs and interested individuals to cooperate in gathering the crop while in good condition, the amount available has increased from less than 1,000 pounds in 1940 to approximately 16,000 pounds in 1945. Last year we had requests totalling 20,000 pounds for the crop of 1946. It seems fairly certain that with new trees continually reaching acorn-bearing age—about 20 years—sufficient acorns should be available in California to supply all reasonable demands for planting stock within the United States. It has been determined that fresh acorns of cork oak will average 70 to the pound and that a germinative per cent of about 90 is a normal figure. Thus with a very liberal allowance for losses in transplanting and handling it is possible to obtain at least 100,000 seedlings per ton of acorns.

It is possible to find a few flowers on cork oak trees during any month in the year, but the main blooming period in California is from about April first to the middle of May. The acorns apparently require six or seven months to ripen, and fall from the trees in largest volume from about November 15 to the end of December. The flowers are evidently self-pollinated in many cases, as trees in isolated places often produce good crops of acorns. However, the largest amounts of acorns have been consistently obtained from the plantation at Chico and from street and highway trees in Fresno and Los Angeles counties. It is believed that wind movement induced by passing automobile traffic may be a factor in good pollination and set of acorns on trees adjacent to highways. A great many trees apparently drop most of their acorns when these are very small, and some trees may be self-sterile, as they are said never to have produced any good acorns. However, birds and squirrels must be considered in this matter, as in the grove of fine trees at Kearney Park,

FIG. 3. Removing a ring of cork from a cork oak in Southside Park, Sacramento. Diameter breast high: before stripping, 26.7 inches; after stripping, 24.7 inches; length stripped: 8.5 feet; yield of cork in two cylinders: 78 pounds. The tree is said to have been planted about 1911, but seems to be about 40 years old.

Fresno County, where the pea fowl seem to consume all the acorns before they can ripen.

In order to retain their germinative capacity cork oak acorns must not be allowed to dry out. They usually fail to

FIG. 4. The heavy peavy bar shod with metal is the most useful tool in stripping old trees with heavy bark. Using this it was possible to remove strips up to 10 feet long from the big tree at Napa State Hospital, July 27, 1943.

germinate if kept for a week or ten days in a heated building at ordinary room temperatures. However, they keep all right for several weeks if collected soon after they fall and placed in sacks out of doors in the shade, particularly if the

sacks are sprinkled with water occasionally. If left too long, however, the layer of acorns next to the ground germinates, and the roots break off when the sack is moved. Sacks of freshly collected acorns have been shipped across the country by truck and by railway express with little loss of vitality, but if too long delayed or if exposed to heat, they either germinate or ferment in transit. In either case there will be considerable loss. Dr. N. Mirov of the California Forest and Range Experiment Station has been conducting storage experiments with these acorns since 1941 and has determined that when placed in moist sawdust in tight containers at 38 degrees F. they will retain a high degree of viability for periods up to 22 months and produce vigorous and rapidly growing seedlings. Thus it will be possible in the future to hold acorns from a good crop for growing the following year in case of a crop failure; or they can be shipped under such refrigeration in excellent condition to any part of the world. In most cases, however, if handled expeditiously and kept out of doors, such refrigeration will not be necessary, except for long ocean shipments.

Nursery Practice in Growing Cork Oak

It might seem that the ideal method of growing cork oaks would be to plant acorns directly in place and protect and care for the trees until they are established. But in practice the losses from rodents, competing vegetation and drought have been so severe that direct seeding has rarely been successful. A very few natural seedlings can be found near old trees in some favorable spots. These are generally on good soil, with more than usual moisture available, and in the shade. The last is apparently a very important requirement, so that a lath house must be available for successful nursery propagation. The main problem has been to produce a sturdy seedling in a container which is not too heavy yet which is large enough to permit development of a root system which is not too severely deformed or restricted.

The number ten or one-gallon tin can with holes punched in the bottom has been the container used in propagating some 200,000 cork oak seedlings at the State Nursery. Twelve-inch tar paper pots with a two and one-half- to three-inch diameter have been used by the Soil Conservation Service nurseries and the Institute of Forest Genetics. No survival figures are available, but it seems that the cans have been somewhat more satisfactory, as they contain a larger volume of soil for root development.

When sacks of acorns are received at the State Nursery in December they are left out of doors until the sand beds are ready. Then within a week or two the acorns are spread out in a long bed, four feet in width, and covered with about two inches of light sand. Here in about five or six weeks they germinate, the tap root making rapid growth downward, the shoot developing much more slowly. The cans having been previously filled with sandy loam soil, the trees are dug from the bed during March and April, the roots are pruned to a length of about four inches and the little tree with the attached acorn is planted in the can by means of a dibble. The cans remain in the lath house until the following winter when the trees are large enough for field planting. They are watered by overhead sprinklers at about weekly intervals during the dry season and any side branches are pruned off to give the tree an erect and whiplike form with a height of eight to twelve inches. Pruning of the root induces a branching and somewhat more fibrous root system than is developed without pruning. The tree and container weigh about eight pounds.

The tar paper pots, which are often about half-filled with sphagnum moss, weigh about half as much as the cans, so

are easier to transport. However, their smaller diameter results in a more poorly developed root system in most cases. Also these tar paper containers must be very carefully handled during shipment, particularly when the soil is wet.

Field Planting

During the past six years about 200,000 seedling cork oaks have been distributed to applicants through the cooperation of State Rangers, Farm Advisors, Soil Conservation Service personnel, County Foresters and so forth, and have been planted by hundreds of land owners. Survival has varied with local conditions of soil, planting technique, irrigation and care, but is believed to average about 50%.

One plantation was set out in the spring of 1940 on dredged and relevelled land at Garden Ranch near Oroville, Butte County. The trees were planted from cans on this very unpromising rocky flat, were shaded by small burlap screens and given but one irrigation during the first dry season. When recently examined there were 25% of the original 200 trees still alive. Some were three feet or less in height, but one had reached nine feet and was still making excellent growth. Another planting of 50 trees of the same stock, set out on much better land the same spring, was all destroyed by gophers before the third year.

Some experiments have been made in the use of bare-rooted stock for field planting. It is apparently feasible if the conditions at the planting site are optimum, the trees not too large, and if the move does not involve shipment for a long distance. The best results have been reported by 4-H Club members who obtained trees from a nursery row in Victory Park, Stockton, took them home and planted them the same day. If shipping distances are very long or conditions at the planting site not good, the use of bare-root stock is questionable. The cost of shipping heavy containers of soil is a major problem in the widespread distribution of seedling trees. Thus if some way can be worked out to secure good survival with bare-rooted stock, it will very greatly advance the program.

Stripping of Cork

Experimental stripping of cork oaks was begun by the writer, George D. Greenan, R. S. Waltz, and Farm Advisor, Henry Everett, on July 13, 1940, at the Chico Forestry Station grove in which the trees were 36 years old, and those over eight inches averaged eleven inches diameter outside bark. The largest tree measured 22.5 inches at breast height before stripping. Mr. Greenan had secured a heavy steel cork stripping axe from Portugal which had a curved blade and a handle tapered at the end for use as a pry bar. Two standard pruning saws, hickory pry bars made from double bitted axe handles, a couple of automobile spring leaves and a heavy hammer made up the rest of the tools. We had to start from scratch, as no one could be found who had ever watched the operation in Europe, and the written material available gave very little information on the actual procedure of stripping trees in Spain and Portugal.

The standard pruning saws proved to be satisfactory for making horizontal cuts through the cork, but we found the Portuguese axe quite unwieldy and difficult to use in making the vertical cut without undue injury to the inner bark. During the first afternoon we removed the cork from ten trees to a height of about six feet with less injury to the inner bark as we became more skillful in handling the tools. We soon determined that it was inadvisable to strip trees less than eight inches d.b.h., as the cork is generally quite thin and difficult to remove. From the larger trees the thicker cork separates quite easily at this time of year along the moist cork cambium

layer with a characteristic cracking sound when submitted to pressure from the pry-bars, and with virtually no injury to the inner bark. After the experience of the first day we presented the problem of the vertical cut to Mr. Fanno, saw manufacturer of Chico. He shortly made up a special saw with teeth on the outside of a curved blade. This proved to be ideal for the purpose and we have used it on all trees stripped during the past six years. The sharpened axe handles and steel spring leaves proved to be excellent pry bars for small to moderate sized trees, and we have continued to use them with good success. For large trees with heavy bark we have since developed a heavy pry bar from a standard peavey handle with the toe tapered to a blunt edge and shod with light metal. These two tools have greatly facilitated the work and have made it possible to strip most trees with very little damage to the tender inner bark layer.

The work of stripping at Chico grove was continued until a total of 166 trees had been stripped to an average height of 5.5 feet. In the removal of cork the breast high diameter was reduced from an average of 11 inches to 8.9 inches, indicating that the cork averaged 1.05 inches in thickness. The average yield of cork was 22.8 pounds per tree for a total of 3,783 pounds for the grove. All of this cork was treated by boiling in two changes of water in open metal tanks set up in the grove, in accordance with what is said to be established practice in Europe. It was then baled and shipped with the cork stripped from other trees that year to Baltimore, Maryland, where it was given extensive tests in the laboratories of the Crown Cork and Seal Company. From these tests it appeared that there was no significant difference between cork given this treatment in boiling water and that shipped without such treatment. Therefore, all cork stripped in the succeeding years has been shipped without boiling.

During August and September, 1940, the test stripping was continued on 60 trees at the McGill Ranch near Oakville, Napa County, 15 trees along the State Highway east of Davis, Yolo County, and seven isolated trees growing in Alameda, Sonoma and Santa Clara countries. All of these last trees had much more room to develop than those in the crowded stand at Chico, and those in Yolo, Alameda, Sonoma and Santa Clara counties were growing on soils of very good

TABLE I

SUMMARY OF CORK STRIPPING—1940

	Chico Station	McGill Ranch	Highway at Davis	Misc.	All trees
Number of trees	166	60	15	7	248
Av. diam. outside bark at 4½′ above ground	11.0″	15.6″	17.7″	23.0″	12.7″
Av. diam. at 4½′ after stripping	8.9″	12.2″	14.8″	19.6″	10.2″
Av. thickness of cork	1.05″	1.7″	1.45″	1.7″	1.25″
Av. length of bole stripped	5.5′	6.6′	8.3′	6.9′	6.0′
Total yield of cork in pounds	3,783	4,999	1,053	725	10,561
Age of trees—years	[illegible]	62	25	....	....
Av. yield of cork per tree in lbs. per year	0.63	1.37	2.81	....	....

The largest yield of cork was secured from a 27-inch tree at McGill Ranch, which was stripped to a height of 13 feet. The cork weighed 501 pounds, which indicates an average annual growth of 8.8 pounds for each of its 62 years.

quality. The McGill Ranch trees are widely spaced, but are growing on rolling foothill lands of moderate quality and in association with coast live oak, black oak and other native trees. They have had virtually no care since they were planted in 1878, and are thus about the best demonstration of what may be expected from trees planted on foothill sections of farm lands in the central coast country. A summary of results from these stripping experiments is given in Table I.

During the summer of 1941 test stripping of 24 trees was carried out in the San Fernando Valley section of Los Angeles County in cooperation with the Los Angeles County Forestry Department and City Forester, Fred Roewekamp, of Los Angeles. The trees, now within the city limits of Los Angeles, were planted along Devonshire Boulevard between Chatsworth and Zelzah by the Los Angeles County Forestry Department in 1915. In all, there are about 140 trees which have made very good growth and are nice ornamental specimens. The trees had an average diameter breast high outside bark of 20.3 inches, were stripped to an average height of eight feet and yielded approximately 50 pounds of cork per tree. Most of the trees stripped very easily with virtually no damage to the inner bark. Most of the cork was firm in texture and evidently of as good quality as that procured in the northern part of the state the preceding year. Three isolated trees were also stripped during this season, including the large tree on the Maher property at Campo Seco in Calaveras County, from which some cork had been removed about 1911. The yield of cork from this tree was approximately 350 pounds when stripped to a height of 14 feet. A total of 1,611 pounds of cork from 27 trees was again shipped to Baltimore for testing as to quality.

In spite of war conditions it was possible to carry on some cork stripping of

TABLE II

SUMMARY OF CORK STRIPPING—1942

Location of tree	Age	Diam. at B.H. Before	Diam. at B.H. After	Length stripped	Weight of cork
Deigaard Pl. Duarte in Los Angeles Co.	30 yr.	21.0″	17.0″	10.0 ft.	85.0 lbs.
" #52	30 yr.	18.0″	13.7″	10.0 ft.	93.0 lbs.
" #54	30 yr.	22.7″	15.0″	5.0 ft.	62.5 lbs.
" #56	30 yr.	13.0″	11.1″	3.7 ft.	19.0 lbs.
Library Park, Monrovia	30 yr.?	18.5″	13.7″	8.0 ft.	107.0 lbs.
Monrovia Nursery	80 yr.?	32.0″	27.2″	8.8 ft.	181.0 lbs.
Mrs. Wales, Charter Oak	42 yr.	32.0″	25.7″	9.0 ft.	211.5 lbs.
Corona del Mar, Goleta Santa Barbara County	25 yr.?	21.1″	17.1″	9.6 ft.	87.0 lbs.
Sexton Ranch, Goleta	70 yr.?	29.7″	25.9″	5.0 ft.	121.0 lbs.
1640 Grand Ave. S.B.	30 yr.?	13.0″	11.0″	5.2 ft.	16.0 lbs.
Orella St., S.B. 2505	25 yr.?	9.5″	8.5″	5.0 ft.	10.0 lbs.
" Cor. of Almar	25 yr.?	11.3″	9.5″	5.6 ft.	15.5 lbs.
" at #2525	25 yr.?	10.5″	9.0″	7.2 ft.	20.5 lbs.
Montecito St. #321–A	25 yr.?	17.2″	14.0″	5.7 ft.	61.0 lbs.
" #325–A	25 yr.?	11.9″	9.0″ } forked		
		9.8″	7.0″ } at 2′	6.0 ft.	46.5 lbs.
Bagg Tree, 412 W. Montecito St. Santa Barbara	85 yr.?	33.2″	[illegible]	5.0 ft.	61.0 lbs.

trees during September, 1942, in order to get samples of cork from different locations and to put these trees in condition to produce second growth cork. Data on these operations is given in Table II.

Of the trees listed in Table II the Deigaard tree #56 was very difficult to strip, the cork coming off in small pieces. This was true also of the upper ring from the tree at Monrovia Nursery. This tree seemed to be very dry because of the presence of nursery stock in cans under it which took most of the water. The fine old Sexton tree at Goleta had thin but very tough and resilient cork, but was quite difficult to strip, and the cork came off in small pieces. About the same can be said of the Bagg tree in Santa Barbara which stands on a lawn. Its cork is thin and came off with difficulty, though the tree seems to get sufficient water. Its crown is thin and it may be troubled by some root disease. The small tree at 1640 Grand Avenue was on a dry hillside with virtually no irrigation, and its cork was hard to strip. We had an impression that the season for stripping might be too far advanced for some of these trees, although others stripped with the greatest ease. The total yield from the 16 trees in Los Angeles and Santa Barbara Counties was 1,197.5 pounds of cork—an average of 75 pounds per tree.

On September 10 we moved operations to the San Joaquin Valley, working first on three of the ten trees in Central Park, Bakersfield. These are about 15 years old, are planted in rather a close grove with some coast live oaks and are watered by rotating sprinklers which keep the lower portions of the trunks wet. The cork was soft on all of the trees and quite badly rotted on the third one. The following day we worked on the large and symmetrical tree on the J. R. Morrow Ranch on Grenville Street, Porterville, Tulare County. This tree is about 75 years old and resembles a fine old American elm in its habit of growth. The cork was thick, springy and of excellent texture, but was somewhat difficult to remove because of its depth and irregularities in the inner layers. Later in the month we stripped three of the twelve young cork oaks at Victory Park, Stockton, with the assistance of Park Superintendent Victor Anderson who stated that the trees were not more than 15 years old. A summary of these operations is given in Table III.

During September, 1942, we also worked on the finest group of old trees in California, with the assistance of Palmer Stockwell and the owner, J. T. Kiser. These trees are said to have been planted along an old road near Sonoma Creek sometime between 1850 and 1860, so are probably the oldest cork oaks in the state. It is reported that 25 or more trees were planted at that time, but that all but these four were badly damaged by grazing animals. The old trees have beautifully dense and rounded crowns and are said to have produced good crops of acorns at intervals for many years. Some patches of cork had been removed by curio seekers for many years, and George Greenan stripped a five foot ring from tree #3 in 1940 which weighed 60 pounds. The other trees and several small ones were stripped September 18, 19 and 20. The cork cambium layer was moist and apparently active at this date, and the cork was removed quite easily except from pressure areas in the crotches and at points on the branches 12 or more feet above the ground. The Kiser Ranch is 2¼ miles south of the town of Sonoma in Sonoma County. The trees show moderate infestation from gall wasps which have not seriously damaged them. There is some natural reproduction near them. The results are summarized in Table IV.

Mr. Kiser is of the opinion that some of the smaller trees are sprouts from the old stumps which have survived damage

TABLE III

CORK STRIPPING IN THE SAN JOAQUIN VALLEY—1942

Location of tree	Age	Diam. at B.H.		Length stripped	Weight of cork
		Before	After		
Central Park, Bakersfield	15 yr.?	11.5″	9.4″	5.0 ft.	32.0 lbs.
" " "	15 yr.?	13.5″	11.3″	6.4 ft.	38.0 lbs.
" " "	15 yr.?	12.4″	9.9″	6.5 ft.	44.0 lbs.
Morrow Ranch, Porterville	75 yr.?	42.2″	37.5″	6.0 ft.	204.5 lbs.
Victory Park, Stockton	15 yr.	17.5″	15.0″	6.2 ft.	24.0 lbs.
" " "	15 yr.	15.2″	13.0″	9.0 ft.	35.0 lbs.
" " "	15 yr.	16.0″	13.5″	10.0 ft.	60.0 lbs.

by cattle and finally reached tree size. Assuming that the trees are 85 years old, tree #4 has produced cork at the rate of ten pounds per year, and trees #1 and #2 better than 6.5 pounds per year. The yield of virtually a ton of cork from these three trees indicates that old ornamental cork oaks may be quite a factor in cork production, even without systematic stripping to improve the quality of the cork. It is agreed by most owners and observers that stripping does not impair the ornamental value of the trees, but rather adds to their interest. The smooth pinkish-tan inner bark gradually changes color during six to eight months after stripping, becoming dark red, then brown, then almost black with cracks through which the rapidly forming new cork shows as tan-colored vertical streaks.

The most interesting event of the 1943 cork stripping season occurred on July 27th when through the kind cooperation of Superintendent Mason of Napa State Hospital we were permitted to remove the cork from the largest cork oak in the United States. The tree stands on an irrigated lawn on the north side of the main building and is said to have been planted in 1870 or 1871. Its diameter breast high, measured 58.2 inches before stripping, which was reduced by stripping to 53.5 inches, indicating that the thickness of cork was 2½ inches at this

TABLE IV

STRIPPING OF CORK OAKS, KISER RANCH, SONOMA COUNTY, SEPTEMBER 1942

Tree number	Diameter		Length stripped	Weight of cork
	Before	After		
1	50.2″	48.8″	14.4 ft.	576 lbs.
2	gr. 50.0″	45.0″	8.0 to 11.0 ft.	551.0 lbs.
3			5.0 ft. (1940)	60.0 lbs.
4	gr. 54.0″	49.0″	9.0 to 10.0 ft.	851.0 lbs.
	Note: Trees #2 and #4 fork near the ground so that diameter was measured just above the ground. After stripping the breast high diameters of the branches were on #2—27.5″, 26.0″, and 20.2″; on #4—34.0″, and 25.5″.			
A	11.7″	9.5″	6.3 ft.	39.0 lbs.
B	10.[illegible]″	8.5″	3.7 ft.	10.0 lbs.
C	{ 12.6″ { 10.0″	9.0″ } forked 7.7″ } at 3′	4.5 ft.	38.0 lbs.
D	7.8″	6.8″	6.0 ft. Nat. seedling	14.5 lbs.

point. The cork came off this tree very easily and the cork cambium was so moist at several points on the trunk that water dripped from the sheets of cork as they were removed. The heavy peavey bar was most effective in working on this tree, and in one case we were able to remove a strip of cork ten feet in length without breaking it. All of the cork on the tree was removed to a height of 17 feet above the ground with the exception of that on one horizontal branch. When removed from the base of the tree on July 31, it made a full load for the Pontiac station wagon and weighed 1,050 pounds. Thus this fine tree in its 73 years had been producing cork at an annual rate of 14 pounds for its entire lifetime. The tree showed no set-back as a result of the stripping, the few cuts through the inner bark healed quickly and the new growth of cork is coming along in a vigorous and satisfactory manner.

Three trees about 15 years old, grown from acorns from the big tree, stand beside the ranch road in front of the dairy building on the Napa State Hospital grounds. These trees are somewhat larger and have evidently had somewhat better irrigation than others in the same row. They were stripped July 23, 1943 with the following results:

Tree	Diameter		Length stripped	Weight of cork
	Before	After		
West	12.0″	10.4″	7.7 ft.	40.0 lbs.
Middle	8.6″	7.5″	7.2 ft.	21.7 lbs.
East	11.8″	9.7″	7.1 ft.	27.5 lbs.

Among other interesting trees stripped during the 1943 season were two 50-year-old trees at Kearney Park in Fresno County. The first of these was a fine specimen with two low horizontal branches below which the diameter measured 44.2 inches, the main trunk being 30.6 inches d.b.h. The two branches were so low that they could easily be worked from the ground. The larger one stripped for 15 feet from the trunk was reduced in diameter from 22.2 inches to 19.8 inches; the smaller one stripped to a length of 6.8 feet was reduced from 17.8 inches to 16.3 inches. The d.b.h. of the main stem was 27.7 inches after stripping. The yield of cork was 315 pounds. The second tree measured 20.2 inches d.b.h. outside bark and had a straight clean bole to a height of 15 feet. This tree stripped so easily that we removed a cylinder of cork ten feet long in a single piece which weighed 92 pounds. The diameter breast high measured 16.2 inches after stripping, showing the cork to be two inches in thickness. Besides the 50-year-old trees at Kearney Park there is the fine "mound" grove of a dozen or more trees planted in 1913. All the trees here are flood-irrigated twice during each dry season. They all show some attack by gall wasp, but seem not to be badly affected by this insect. Other trees worked on were in Alameda, Merced, Madera, Fresno, Tulare and Kern Counties. Most of them stripped easily with the exception of one at Jasmine which was the most difficult of any tree we have worked on. The cork had to be forced off in small pieces but was of good quality. Another very difficult tree to strip was a small specimen at Fiddletown in Amador County which yielded only 44 pounds of cork in small pieces. The big tree there which we stripped on September 3 had firm cork of excellent quality which stripped very easily and yielded approximately 250 pounds from 8.5 feet of stem. The breast high diameter was 36.5 inches before and 30.3 inches after stripping. The old inhabitants of this mining town seem to think that this tree was planted about 1856. It has produced very good crops of acorns. This same week we stripped the fine old tree at the deserted mining town of Todd's Valley in Placer County

at 2,700 feet elevation, which puts it in the lower portion of the ponderosa pine belt. The tree was probably planted in the yard of a nice residence about 1860 in a place not disturbed by the old drift and hydraulic mining operation. The property is now owned by Mr. T. de-Roode of New York who went with us to see the operation. Cork was removed to a height of 7.2 feet for a yield of 185 pounds. Some of the ridges of cork were six inches in thickness and the cork was of excellent quality. Diameters breast high were 38.3 inches before and 33.4 inches after stripping. Only two or three buildings are now standing in the area which between 1850 and 1861 is said to have had a population of 12,000. The old mining areas near the tree are coming up to a fine stand of young ponderosa pine.

On September 29, 1943, we stripped ten small trees at Chico Station grove in order to test the effect of paint and other coatings of the inner bark applied within one hour of the time of stripping. The trees stripped just as easily on this date as they had earlier in the year. The coatings used were *a*) tan colored porch and deck paint; *b*) blue flat wall paint; *c*) "Opex" colorless lacquer; *d*) thick sodium silicate solution; *e*) cream colored kalsomine; *f*) heavy builder's paper tied with twine. Later examinations seem to indicate that the tree wrapped with paper made the best recovery and most rapid growth of cork. The tree coated with the colorless lacquer died. The other applications seemed to have little effect on the development of new cork on the stripped portion of the trunk.

During the 1944 season trees were stripped in Alameda, Merced, Fresno, Kern, Los Angeles and Ventura counties with about the same results as indicated above. The following may be mentioned as most interesting: One of the 31-year-old "Mound" trees at Kearney Park, Fresno County, measured 31.4 inches below the fork outside bark before stripping and 28.6 inches afterwards. Ten feet of stem yielded 165 pounds of cork which came off very easily. The cork oak on the lawn of C. H. Powers, 230 Citrus Avenue, Azusa, is 54 years old, 65 feet tall with a clear length of over 20 feet and is one of the most beautiful cork oaks in Los Angeles County. It was stripped to a height of 10.5 feet on August 18, the excellent quality cork easily coming off in two perfect cylinders. Stripping reduced the d.b.h. from 35 inches to 29.2 inches, and the yield of cork was 235 pounds. The finest cork oak in Ventura County stands in a citrus grove on the property of R. H. Peyton near the Rancho Sespe at Fillmore. It is approximately 60 years old and is said to have been given as a premium by the San Francisco Call Bulletin. The tree has always received good irrigation and cultivation and has had plenty of room to develop, as it towers above the orange trees. It measured 40 inches d.b.h., 50 feet tall with a clear length of ten feet, and a crown diameter of 60 feet. We stripped 5.3 feet of stem leaving the d.b.h., after stripping, 35 inches, showing that the cork was 2½ inches in thickness. The cork stripped easily though not in one piece and seemed to be of excellent quality. The yield was 200 pounds. The tree is a beautiful ornamental specimen, is in excellent condition and shows little evidence of attack by gall wasps or other enemies. This appears to confirm the opinion that gall wasp attacks are apt to be most serious on those trees which are growing on poor soil or suffering from a deficiency of moisture.

During the 1945 and 1946 seasons stripping of trees was confined to a series of method demonstrations arranged by Farm Advisors in different counties for the benefit of those who had planted trees and were interested in methods of harvesting cork.

Regrowth of Cork After Stripping

At the time of stripping the cork cambium is in active growth and quite moist. It soon dries to a depth of about one-eighth of an inch into the sheath of inner bark remaining on the tree, and during a period of months it goes through the series of color changes from pinkish-tan to dark brown. The new growth of cork starts from re-established cork cambium below this dried "hardback" layer exposed to the air. The recuperative powers of this inner bark layer are quite remarkable, and production of new cork is so rapid that within a few months the bright tan color of the fresh cork can be seen through vertical cracks in the dry outer layers. By the act of stripping, the tree appears to be stimulated into great activity for the rapid replacement of the protective layers of cork. Also the healing of wounds, which may have been made through the inner bark to the cambium layer, is very rapid on all trees in vigorous condition. After losing about half of its thickness from the drying, the inner bark layer evidently remains thinner than it was for a number of years, all energy appearing to go into the formation of cork. In order to test the vigor of this inner bark layer, tree number 6 at Chico was stripped a second time in 1943 [illegible] complete removal of the [illegible] cork to the same [illegible]. This tree yielded 13 pounds of cork at the original stripping and measured 7.4 inches d.b.h. after the cork was removed to a height of 6.2 feet. In 1943 it measured 8.9 inches before stripping and 7.9 inches after removal of the ring of second-growth cork which weighed 14 pounds—one pound more than had been originally taken from the same trunk area three years before. Later examinations of this tree indicate that it is still in vigorous condition and putting on a third growth of cork.

It has now been possible to remeasure a considerable number of trees in order to give an idea of their recovery after stripping and the development of "second-growth" cork during a five-year period. Results which are summarized in Table V show such rapid growth that the diameter outside bark before stripping has generally been regained and often exceeded at the time of the second measurement.

One of the Davis trees (5-S), which measured 16.5 inches in diameter before and 14.2 inches after stripping in 1940, was restripped in September, 1945, when its diameter had [illegible] inches. By removal of about [illegible] pounds of second [illegible], the diameter was reduced to [illegible] at breast height, which indi[illegible] a growth of about four inches in diameter for the wood cylinder of this tree in five years. This is in marked contrast to the much slower growth of the crowded trees on poorer soil at Chico. On July 7, 1946, a cylinder of cork 4.3 feet long was removed from tree 3-N in this highway planting, the yield of cork being 59 pounds. Its diameter had been reduced from 19.1 inches to 16.7 inches by stripping in 1940. It had grown to a d.b.h. of 26.2 inches in the six years

TABLE V

REGROWTH OF CORK [illegible] AFTER STRIPPING

Location	[illegible] trees	[illegible] D.B.H. Before	After	5 years later
Chico, Butte County	148	(1940) 11.03″	9.05″	(1945) 10.7″
Davis, Yolo County	18	(1940) 17.2″	14.4″	(1945) 22.2″
Chatsworth, Los Angeles County	13	(1941) 22.7″	20.4″	(1946) 23.8″

which was again reduced to 23.2 inches at a point just below the upper edge of stripping. The cork, therefore, had grown to a thickness of 1.5 inches in the six years since stripping and seemed to be of very good quality, being at the rate of about 18 pounds per year for this tree which is now 58 feet tall at 31 years of age. Very similar yield of cork was indicated from the Chatsworth trees growing on similarly good soil when 53.5 pounds of very good cork were removed from four feet of stem of tree (N-2) August 6, 1946. Its diameter before stripping in 1941 had been 23.0 inches with recovery to 22.9 inches in the five years. After the second removal of cork it measured 20.4 inches diameter at the top of the stripped portion. The cork again seemed firm and of very good quality.

In order to obtain a comparison of growth on unstripped trees, 13 of the Chatsworth trees were selected which had virtually the same diameters in 1941 as the 13 stripped trees. Average d.b.h. was 22.9 inches in 1941 as against the 22.7 inches shown in the above table. After five years the unstripped trees showed an average diameter of 25.4 inches as compared with the recovery to 23.8 inches by those from which bark was removed in 1941. Thus if the average bark diameter in 1941 (2.3 inches) be subtracted from the average diameter for 1946, we get a calculated d.b.h. of 23.1 inches for the unstripped trees, while the actual measurement of the stripped trees was 23.8 inches. Though some of this must be assigned to wood growth, it is further indication of the stimulation of cork production by stripping. Individual trees for which records are being kept indicate similar rapid growth after stripping. The Boyle tree which stands on irrigated lawn at 1337 Highway 99 in Kingsburg, Fresno County, was stripped in August, 1943, to a height of 8.75 feet when it was 13.5 inches diameter outside the cork and 11.0 inches after stripping. It was then about 18 years old and the yield of cork was 51 pounds. In August, 1946, after only three years it measured 14.8 inches d.b.h. and is making an excellent growth of cork.

During the past six years nearly 500 trees have been stripped in California with a total yield of approximately 15 tons of cork. Most of the trees have released their cork quite easily and with very little injury to the inner bark. Any damage to inner bark or cambium layers is usually healed over very quickly where trees are in vigorous condition. Only three trees have died following stripping, and it appears that these were suffering from excessive drought or were otherwise in poor condtion. Stripping has been conducted from July 1 to early October with little apparent difference in ease of stripping during the season. We feel that stripping should be confined to trees in good growing condition and with vigorous and full crowns. Such trees show very little setback as a result of cork removal.

As a result of this work, the following tentative estimates of yield are suggested as possible for cork oaks growing in California under good conditions:

TABLE VI

TENTATIVE ESTIMATE OF CORK YIELD PER TREE

Age	Yield in pounds
10 years	None
20 "	15 to 20
30 "	30 to 50
40 "	50 to 75
50 "	75 to 100
60 "	150 to 200
70 "	250 to 400
80 "	500 and up

If trees were stripped every eight to ten years beginning at about 20 years, it seems likely that the resultant stimulation may increase the estimated yield

in the above table by one and one-half to two times. It appears that the cork produced by trees on good soil and making vigorous growth is of about as good quality as that from trees on poorer soil or drier conditions. This may not hold true for higher quality cork articles, such as wine bottle corks, but the cork from fast growing trees seems to be fully suitable for composition articles and insulation blocks.

Quality of California Cork

During the last six years about 15 tons of cork have been stripped from California trees and shipped for testing to Dr. Giles B. Cooke, Research Department, Crown Cork and Seal Company, Baltimore, Maryland. He has made several grinding tests and a considerable number of composition cork articles which he says are very good. He reports as follows on one of the typical shipments:

"The total weight of the bales used was 1978 pounds, of which 239 pounds (12% of the shipping weight) was in the wrapping and baling material, leaving 1739 pounds gross weight of cork. In grinding, granular particles of three standard sizes were produced for a total of 686 pounds, or 39.44 percent of the sample. This cork is of excellent quality and can be used in the manufacture of composition cork for closure liners, gaskets, cork sheets and many other purposes. Other very small but usable particles (30 to dust) amounted to 413 pounds or 23.75 percent of the sample. This very fine material is not suitable for composition cork to seal foods and beverages, but may be used in linoleum, shoefillers and other commercial articles. Thus 63.2 percent of the material is useful in industry, leaving 36.8 percent as nonusable hardback, moisture *etc.*"

Dr. Cooke says, "The results of this work are most encouraging and I see no reason why this cork cannot be used interchangeably with the imported grade."

One lot of cork amounting to 1,692 pounds was forwarded by Dr. Cooke to the Armstrong Company and was tested in their Camden Plant to determine its suitability for producing corkboard. Mr. A. L. Jennings reports on these tests as follows:

"This material was ground and sized through the regular production equipment. The three-quarter to ten mesh material was made into corkboard in the regular steam baking molds according to standard practice.

"The slabs as received contained a high percentage of "Red dog" and the cork was very brittle. These characteristics resulted in a low yield of three-quarter to ten mesh cork. The ground cork showed a definite tendency of the particles to be rounded instead of having an irregular fracture. The particle size of the three-quarter to ten mesh cork was very uniform and contained little or no fines.

Gross weight of sample	1692 pounds at 16.45% moisture
Ground cork (3/4 to 10)	789 " " 1.1 % "
this equals	46.63% of the gross
By-products obtained:	
size 20 to dust	268 pounds
10 to 20 hardback	285 "
10 to 20 airfloat	90 "

Screen analysis of ground cork:

Retained on .525 Mesh	4.0%	Average weight 7.0 pounds per cu. ft.
" " .371 "	34.0%	
" " #3 "	42.6%	
" " #6 "	18.8%	
" " #8 "	0.6%	

"Blocks were baked from 100% of the subject cork and from mixtures containing 25, 50, and 75% of foreign cork. This domestic cork has much the same effect upon the baking of corkboard as has foreign young limb virgin cork. Data showing typical mixes and average physical properties of the baked block are as follows:

Block No.	Mixture	Bake-out Loss	Density lbs/bd/ft	Modulus of Rupture lbs/sq/in	Deflection inches
1.	100% domestic	16.9%	.631	25.9	.69
3.	100% "	20.4%	.589	28.1	.83
7.	75% " / 25% regular	18.7%	.654	28.4	.67
9.	50% domestic / 50% regular	17.7%	.641	16.1	.48
11.	25% domestic / 75% regular	17.7%	.612	22.5	.59
17.	100% domestic	17.4%	.602	26.0	.63

"From the above table it will be noted that all samples met the requirements of Federal Specification HH-C— 561b excepting board #9 which failed to meet the modulus of eighteen pounds."

It appears from these two reports that from 50% to 60% of the weight of cork samples shipped can be utilized for commercial articles of good quality.

Enemies of the Cork Oak

Young trees of cork oak are subject to severe damage by gophers, rabbits, domestic live stock and deer. It is necessary to give them protection from these animals for several years after planting. In most parts of California the seedlings must have shade and one or two irrigations during the dry season if satisfactory survival is to be expected. In most cases it is advisable to remove competition of grass, weeds and brush during the first few years.

The most serious pest is evidently the tiny gall wasp *Plagiotrochus suberi* which seems to be well distributed throughout California. Eggs are laid on soft bark of small twigs which swell as the larvae develop and later turn brown and die from the numbers of tiny emergence holes. Attacks of this insect seem to be worse on trees which are suffering from drought or poor soil. Many have become so unsightly from dead twigs and thin crowns that they have been removed. The common California oak moth will occasionally defoliate cork oaks but may be controlled by spraying. There is no known control for the gall wasp.

At least one cork oak in California is known to have died from oak-root fungus *Armillaria mellea*. This tree stood in the old Hihn residence gardens in Santa Cruz. It may be that the Bagg tree in Santa Barbara was also attacked by this fungus which is undoubtedly more apt to attack trees growing on irrigated lawns. Planting stock with deformed or damaged root system is quite susceptible to attack by this parasite. The best defense against these insect and fungus enemies is to use sturdy planting stock and give the trees good protection and care until they become well established.

Summary

Cork oaks have been planted in California since about 1855, and there are some outstandingly fine specimen trees growing from San Diego to Eureka at elevations below 2,700 feet. There are about 5,000 trees more than ten years old in the state.

Cork oak acorns produced in California average 70 per pound, have a high germinative capacity which can be maintained for twelve months or more by moist cold storage at 38° F., and during most years it should be possible to obtain from five to ten tons of cork oak acorns from California trees.

During the past six years about 200,000 seedling trees of cork oak have been grown and distributed to land owners

under the cooperative cork oak project. Where carefully planted, protected from animal damage and given adequate irrigation, shade and care, many of these plantations have shown excellent survival and growth.

Because of the kind interest and cooperation on the part of owners of cork oak trees, it has been possible to carry on experimental stripping of about 500 cork oaks during the past six years. The stripping season has been found to be from about July 1 to early in October. Most vigorous and full-crowned trees can be stripped easily with the special tools developed and with virtually no damage to the inner bark. It is not advisable to strip trees which are thin crowned or suffering from drought, insects or disease. Removal of cork from ornamental cork oaks changes their appearance but does not seriously affect their growth or lessen their ornamental character.

The 15 tons of cork has been quite thoroughly tested and found to be well suited for the making of composition cork articles, insulation blocks and other commercial articles. It is reported to be fully interchangeable with Mediterranean cork of similar character and grade.

Regrowth of cork after stripping has been rapid and satisfactory with trees, usually regaining the diameter before stripping in five years. Indications are that the reproduction cork is of excellent quality. Trees 25 to 30 years of age when stripped have put on a growth of 100 pounds of reproduction cork in five years.

The most serious insect enemy of the cork oak in California is the gall wasp which kills many twigs, particularly on trees in dry locations. There is no known control for this pest.

If the cooperative distribution of trees can be continued until there are one million cork oaks growing in California, they will when 30 years old contain an emergency supply of 50,000 tons of cork. This amount may be increased and the quality improved by successive stripping of the trees after they become 20 years of age.

Utilization Abstracts

Medicinal Plants in Britain. "Reports indicate that the valuable collections of medicinal plants made during the war are not being continued this Summer, with the possible exception of Raspberry leaves, which are being tested for their reputed usefulness to midwives. Britain is presumably reverting to the pre-war 'Mad Hatter' arrangement regarding Digitalis, of which we need four hundred tons a year. Britain grows the best and most potent Foxgloves in the world (the Welsh plants are particularly good), yet in ordinary times we do not produce our own Digitalis. We export seeds to Russia, where Foxgloves do not grow wild but are cultivated, and the Russian-produced Digitalis, made cheap by ill-paid labour and a heavy State subsidy, is then exported to Britain. The only natural advantage enjoyed by the Russians is a climate which permits the leaves to be dried without artificial heat—which was, of course, provided for the purpose in Britain during the war. The position of certain other imported drugs is only one or two degrees less preposterous. For example, the wild Autumn Crocus which yields colchicine, is so abundant in some western counties that it is (by reason of its poisonous character) a serious pest in farm pastures". (*Anon., Gardeners' Chronicle 119: 276. 1946*).

Timbers of British Honduras. "Notes on forty-two secondary hardwood timbers of British Honduras", issued in 1946 by the Forest Department of that country, describes the properties and uses of such timbers. (*A. F. A. Lamb*).

Minor Fiber Industries

In which Spanish moss, Palmetto palm, Spartina grass and Teasel bur each plays its role by contributing to the manufacture of particular commodities.

BRITTAIN B. ROBINSON*

Introduction

MANY readers are familiar with the major plant-fiber-producing industries of the United States, namely, those of cotton, broom corn, flax and hemp, but are not familiar with the fiber industries of lesser renown. It is the purpose of this article to discuss four of these so-called minor industries, namely, those utilizing Spanish moss, palmetto, Spartina grass and teasel. Among these industries it is only with respect to palmetto and Spanish moss that fibers are extracted from the plants, as is done with cotton, flax and hemp, but the utilitarian value of the others is largely dependent upon their fiber content, as is true also of broom corn, and their utilization is thus appropriately included in the category of fiber industries.

References on the subject reveal that there have been sporadic attempts in this country to produce fiber from yucca, crotalaria, jute, abutilon, milkweed, apocynum, nettle, cattail, ramie and other plants than those mentioned above. All these attempts, with the exception of those involving ramie, have not resulted in any long period of continuous production. At present, production of ramie is under way on a rather extensive scale in Florida, and it is hoped that a continuously profitable industry will result from these experimental undertakings.

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The United States is fortunate in covering a large area from the semi-tropics to the cooler temperate regions, within which one is able to find regions of different climates and soils that are capable of growing a wide variety of plants. Unfortunately the fact that many plants can be grown in the United States does not mean that an industry producing them here would be profitable. Another country may have equally favorable soil and climate, and, in addition, have the advantage of cheap labor. It is under such conditions that jute, for instance, is grown in India, whence we import large quantities of it that are consumed in greater amounts than all other plant fibers combined, with the exception of cotton. There are, however, many cordage, brush and broom fibers as well as plant fiber fillers imported into this country which are obtained from strictly tropical plants that could not possibly be grown within the continental United States, and imports of those fibers are necessary to sustain our manufacturing industries using them.

The purpose of this paper, as already stated, is to describe the Spanish moss, palmetto, Spartina grass and teasels industries. It is hoped that the discussion will lead to a better understanding of the industries in reference to their competitive fields and their future potentialities.

Spanish Moss

The material known by the names "Spanish moss", "Southern moss",

"Florida moss" and "Louisiana moss", and its commercial form "Black moss", is not a true moss, but a plant or the product of a plant belonging to the pineapple family. Its botanical name is *Tillandsia usneoides* L. It is a true epiphyte, growing on either live or dead trees, or sometimes even on telegraph and telephone wires. It is distributed from the Dismal Swamp of Virginia along the coast to Florida, and westward to Louisiana and Texas. Other species of the same genus extend southward in the Gulf region through Mexico to Central America. It grows luxuriantly in very moist localities.

The moss is collected when there is a slack in other work, and is often gathered by individuals to obtain an immediate cash return upon delivery of the harvest to a moss company. The material is pulled from trees with hooks or rakes on long poles, or it may be collected on the ground after storms which blow it down. A large part of the Louisiana output is fallen moss gathered from the bayous where it drops from the cypress trees. Sometimes it remains under water until cured. Frequently a man working in a tree will have a boy on the ground removing sticks and leaves from the moss pulled down. In dense growths of it a collector can pull down and gather, free of sticks, 100 pounds in an hour, but the average collection may be closer to 500 pounds per day.

The green moss is purchased from the collectors by moss-ginning companies which may operate a number of curing yards not located at their gins. A large number of such yards are scattered around central Florida, for the green or gray moss is not considered of sufficient value to transport great distances to the gins. After curing, the moss is trucked from the curing yard to the gin. In addition, the companies send out trucks to buy cured material from scattered collectors. The cured moss may be purchased beside the road, but no green moss is ordinarily bought by the trucks. The collector trucks his own green moss to the nearest curing yard.

In curing moss in Florida the material is placed in long piles, approximately 20 feet wide, 100 feet long and six feet deep. It is then watered, and during the watering and tramping which may occur in watering, the pile settles one to one and a half feet. Then it is not touched for six weeks, after which time it has settled to 18 to 24 inches in depth. The outer moss is still gray, but that under the surface of the pile is now brown to black. Longer curing in the beds is necessary to get a good black product. During the curing considerable heating, resulting from biological activity, occurs in the bed.

The moss after curing is placed on wire racks to dry. In some cases the beds are opened and small piles are made on the ground to facilitate drying before the mass is moved to the racks.

Various estimates are given for loss in weight during curing. For brown moss the loss may be 60% to 75% and for black moss as much as 80%. These are losses in the curing alone. Further losses occur in ginning. In ginning black moss that has lost 80% in curing, half of the remaining weight is subsequently lost so that the final yield is 10 pounds of black moss per 100 pounds of green moss. The yield is higher for brown moss, but losses may be 60% to 70% in ginning. The yield from moss collected in winter is higher than from that collected in summer. One estimate was that the summer yields are only one-half of the winter yields. This is due to new growth of the summer harvest which has little recoverable fiber.

In ginning, the cured dry moss is fed into a kind of gin consisting of fluted rollers and a toothed cylinder which may or ~~may not~~ work against a toothed concave surface. After passage through

the gin the moss is shaken over a wire screen or latticework floor to free the fiber of loose bark. The fiber is then sorted for color and cleanliness and baled for market.

In August, 1946, the price paid in Florida for green moss ranged from 70¢ to possibly $1.00 per 100 pounds delivered at the moss yard; the price for cured moss was $5.00 per 100 pounds. Most moss is purchased green. In 1937 green moss was bought for 25¢ per 100 pounds and cured moss for $2.50 per 100 pounds.

The Office of Price Administration had ceilings on the sale of moss during the first half of 1946, $17.75 per 100 pounds of black moss, $16.25 for brown moss. Very little black moss was produced in Florida under these prices, as the gins claimed that too much weight was lost in curing moss until it was black for the slight additional increase in ceiling price.

The refined black moss is sold by the ginning companies largely to upholsterers' supply firms which in turn sell it for use in furniture cushions. It has also been employed in the cushions of automobiles and railroad cars, being well adapted for such use because of its great resiliency. Among other plant fillers used for similar purposes are kapok, cotton linters, crin vegetal (shredded palm leaves,) sisal waste, cocoa fiber, flax tow and excelsior. Cotton linters, flax tow, Spanish moss and excelsior are of domestic industries.

The annual production of Spanish moss in Louisiana has until recently outranked that of Florida. Some estimates place the Florida amount in 1946 over 4,000,000 pounds of ginned moss. Older references have indicated an annual production of nearly 10,000,000 pounds for the United States.

Cabbage Palmetto

There are about half a dozen species of palms called "palmetto" growing in the Southern States, chiefly Florida. The most important of these as a fiber plant is *Sabal palmetto* (Walt.) Lodd. It is commonly known as "cabbage palmetto", but also is called "Carolina palmetto". It is native to Florida and the region northward along the coast to North Carolina. In Florida it is distributed all over the State except the extreme northwestern portion. It is normally an erect tree attaining a maximum height of 80 feet with a trunk diameter of two feet or less. The trunk is clothed during early life with old "boots" remaining from decayed leaf-stalks. As the tree grows older these fall away, leaving a fairly smooth, slightly ridged stem. The leaves are fan-shaped and shiny, reaching a maximum length of about five feet and a somewhat greater breadth. The slender unarmed petioles attain a length of seven feet. The dark colored or black fruits average about one-third inch in diameter. The cabbage palmetto is found growing in marshes, hammocks and sandy soils, and because of its adaptability to various soils it can be grown as an ornamental throughout most sections of the southeastern coastal section. It is not damaged by cold in Florida.

The palmetto produces a valuable fiber from the "boots" surrounding the terminal bud or cabbage. Recovery of this fiber for use in brushes has been a Florida industry for more than 50 years. In 1897 Charles Richards Dodge, in U. S. Department of Agriculture Fiber Investigation Report No. 9, described the preparation of this fiber by a factory located in Jacksonville, Florida. At present there are at least four mills in Florida engaged in this work. These mills have been estimated to produce 500,000 to 1,000,000 pounds of cleaned, prepared fiber annually. Further, it has been estimated that with more systematic management of harvesting it would be possible to increase the production from two to three times the present production, and some estimates are even ten

times the present production before reducing the supply of productive trees. However, due to lack of systematic management, the economic productive areas have probably tended to decrease in recent years. When it is realized that each bud yields only one and a half to three pounds of fiber, possibly averaging about two pounds, it will be understood that at present some 250,000 to 500,000 trees are used annually by this industry.

The palmetto fiber is in the "boots", or spathes of the leaf stems, which surround the "bud", or "cabbage", and in securing the bud surrounded with the upper leaf boot stems, the tree is sacrificed. The buds, usually three to four feet long and about ten inches in diameter, are cut out of trees in large groves and are trucked or shipped to the mills for processing. They average about 50 pounds in weight, but may weigh as much as 100 pounds, and contain a very high percentage of water when harvested. Buds of the above size are preferably obtained from trees six to eight years old. Although their removal results in the death of the trees, a grove of palmettos may be systematically harvested every three to five years, since removal of the larger trees gives more sunlight and nourishment to the small trees in the undergrowth, resulting in an area becoming even more productive after the first and second cutting than at the time of original cutting. Buds are not harvested from many old groves where the palms are very tall. If the palm trunk is taller than ten feet it is considered uneconomical to harvest it, for a tall tree necessitates a cutting to fell it and another cutting to remove the top three or four feet containing the bud.

The buds should be delivered and processed before becoming too dry which results in oxidation and deterioration. In summer during warm weather the buds may be kept only about ten days, but in winter about 30 days of storage is possible without too much drying.

The buds upon arrival at the mill are placed in large cement tanks and boiled for two or three days. The cooking softens and loosens the mass of boots surrounding the bud, permitting them to separate from one another when removed from the tanks and crushed between rollers. The desirable fiber is mainly on the outside of the boot; the inside has a cross net of fiber that is removed. The pulp and undesirable fiber is removed by holding the crushed boots against a revolving drum which is covered with hackle pins that shred and comb away the waste from the marketable fiber. The fiber is then dried, oiled, sorted, trimmed to desired lengths and packaged.

The fibers are from 9 to 42 inches in length, but mainly about 24 inches. Fiber at the butts of the boots is coarser than at the tips. Further, plants growing in swamps have possibly coarser fiber than those growing on higher dry ground. Yellowish brown is considered the best color, although much fiber may be a deep brown. Yields of fiber vary, depending somewhat on the water content, a moist bud containing about 5% dry fiber.

The fiber is largely used for brushes in breweries, creameries, citrus factories, *etc.*, where it is desired because it remains stiff in hot water and caustics and does not soften and become a mop, as occurs with some brush fibers. Its chief competitor in this field is Palmyra, a brush fiber imported into the United States from India where it is obtained from the Palmyra palm, *Borassus flabellifer* L. Palmetto fiber is also used extensively in whisk brooms.

Although the palmetto has been utilized mainly for brush fiber, it has a number of other minor uses. In preparing the finished fiber, there is some waste material obtained in combing and shredding, and some from cutting to specified market lengths. This waste fiber has been sold for upholstery, but little is used for that purpose at present. The

waste has been used also for bulk heads for docks, and has been suggested as a substitute for coir in matting. However, one manufacturer who tried the waste stated that it is not so flexible nor so strong as coir.

The buds of *Sabal palmetto* have been prized by the Seminole Indians as an article of food, for which purpose they are boiled after being removed and trimmed. They are pickled and preserved in Florida at present to a limited extent. The terminal tufts of young uncurled leaves are removed by the Seminole Indians to ship to churches for use on Palm Sunday. Removal of the leaves for this purpose does not kill the plant as does removal of the bud. Handicraft specialists of the Florida State Markets have encouraged use of the leaves for basketry. In some cases the entire leaf is made into a fan, but in other cases the segments of the leaf are stripped lengthwise into strips about a half inch wide, which may be dyed and then woven into baskets or similar articles. The leaves have also been shredded and used to some extent for stuffing cheap mattresses; and as a substitute for hair in plastering and stucco work. They have also been used as a substitute for broomcorn for brooms, and at one time a company was organized to make twines and rugs from shredded segments of the leaves.

The rootstocks contain tannin, and various efforts have been made to extract this component for use in tanning leather, but thus far the work has not proved to be profitable. The trunks are used for small wharves or docks, because it is stated that they are practically immune to injury from the teredo, a water mollusk that bores into other woods used in salt water.

Saw Palmetto

The common saw palmetto, *Serenoa repens* (Bartr.) Small, is found throughout the State of Florida, in southern Georgia and to some extent in Alabama, Louisiana and South Carolina. It usually grows on uncultivated tracts or in the undergrowth of pine lands. It is a low shrub usually with a recumbent trunk that frequently may be just under the soil. The leaf stalks are slender but bordered with small sharp spines. The leaves are fan-shaped.

Many attempts have been made to utilize this plant to some economic advantage. The leaves and stem fibers have been used to some extent in the past as an upholsterer's filler, in brushes and in plaster, but no extensive utilization of importance has developed.

The berries are employed in medicine and have been collected and handled by one or two firms in Florida. Their value is believed to be low, and just covers the cost of collecting.

During World War II a factory was erected in Florida to utilize the pulp from the root-like trunks in cartridge plugs and for wall board. The fiber removed from the trunks was experimentally prepared for cordage, but by abaca and sisal standards it was of low grade for that purpose.

Spartina Grass

In the United States the most important broom or brush fiber plant material is broom corn of which there is grown annually approximately 300,000 acres that produce 40,000 tons of broom material. The brooms are used in nearly every household, and in many industrial mills. Spartina grass from Florida, Louisiana and Missouri, nolina shredded leaves from New Mexico and rice straw of domestic origin are substitutes for broom corn. Utilization of the last two is sporadic, but Spartina grass apparently has been able to compete year after year until it deserves the name of an industry.

This plant, *Spartina spartinae* (Trin.) Merr., is a grass that grows in large

dense tufts without rhizomes; the culms are stout, one to two meters tall; blades are narrow, firm, strongly involute; spikes are short and appressed, closely imbricate, forming a dense cylindric inflorescence 10 to 30 cm. long; spikelets are closely imbricate, six to eight mm. long; glumes are hispid-ciliate on the keel, the first shorter than the lemma,

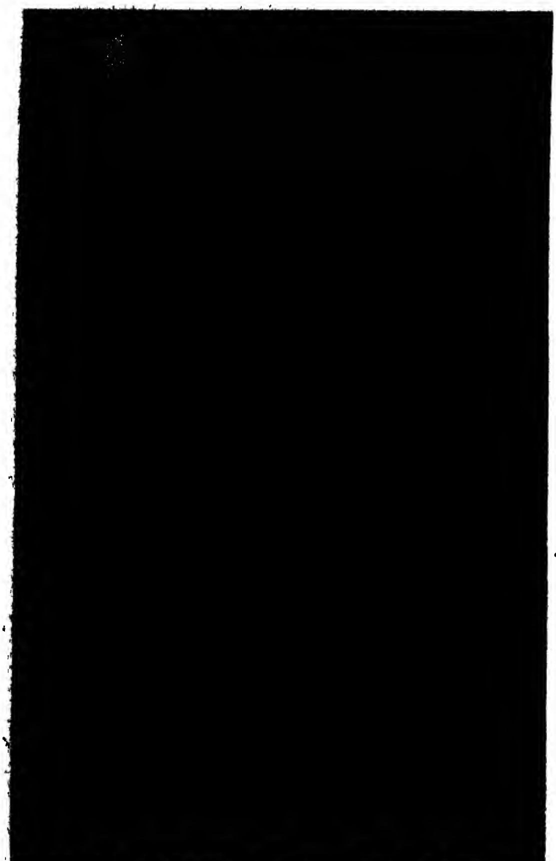

Fig. 1. A bale of fibers obtained from Spartina grass, *Spartina spartinae*, to be used primarily as a substitute for broom corn in the manufacture of brooms.

the second usually a little longer. The plant is distributed in marshes, swamps and moist prairies near the coast from Florida to Texas and eastern Mexico.

Several other species of spartina have also been utilized in the United States for many years. The culms have been used in brooms, matting, paper, stock food and as a packing material. Reports indicate that they may have potential high value for paper. The conclusions of an analysis by a paper mill at Quincy, Illinois, in 1906 was that spartina fiber was superior to esparto, *Stipa tenacissima* L., for paper. The mill at Quincy used from 3,000 to 7,000 tons annually for making box-board at the beginning of the 20th century.

Large areas of spartina are found near Titusville, and on Meritt Island, Florida, where the grass has been utilized for many years. It has been collected to some extent between Lakeport and Brighton, Florida. It substitutes for broom corn in the center of the broom, and utilization in this capacity has been primarily in periods when broom corn was high priced.

Arrangements are made with land owners where this wild grass may be found in large stands for permission to harvest it. In some cases the lease right amounts to 50¢ per ton for the privilege of harvesting. The harvesting may be and is performed the whole year round. In this respect it differs from the harvesting of Missouri grass or "Rippey", *Spartina pectinata* Link., which is harvested seasonally for a few weeks in the summer in Missouri. In Florida the old stands are burned over in order to get a new growth of green culms without a mixture of older culms. It requires about 90 days for a new growth after burning before harvesting. After two or three harvestings the stand is believed to be poorer. On uplands in the vicinity of Titusville the stands may be weedier. As far as is known, the grass has not been cultivated, although plans to conduct tests toward that end have been made. Tufts covered for several months with water die.

Harvesting is performed with a hand sickle. In Florida the harvesters received $1.75 per 100 pounds of dry straw in August, 1946. Two harvesters may cut one to one and a half tons of dry culms per day. After cutting, the culms are

placed on top of the stubble of the tuft to dry. Drying and curing require about a week, after which the harvesters place the culms in large bundles, cover the bundles with burlap and then carry them to the nearest road. In southeastern Louisiana the harvesting methods were the same a number of years ago, but the grass, *S. pectinata*, after harvesting was moved by small barges to the nearest highway. The harvesters were forced to wear hip boots and were unable to cut during high tides, as the grass was then partly under water.

The advantage of collecting spartina in the area between Lakeport and Brighton, Florida, has been that it may be harvested with a binder, a practice that is permitted by dry ground in more accessible areas.

Hand harvesters, to facilitate bundling, have been observed to use a light wooden saw horse with projecting upright legs on which burlap was stretched and the straw then placed upon the burlap. The harvester's job is complete when he carries the dry straw to a roadway, whence it is trucked to warehouses. There, in crude, inexpensive but effective presses, it is made into cylindrical bales, pressure being applied by tightening ropes around the straw. The bales weigh about 220 pounds and are 36 inches long and about 28 inches in diameter. The straw is placed in the bales, one handful at a time, alternating the heads with respect to direction. The loose ends of grass sticking out at the ends of the cylindrical bales are cut off with a pair of garden or hedge shears, and the bale ends may be pounded even with a large wooden paddle, on one side of which there are pins to make a hackle. The hackle is used in straightening any crooked culms.

A bright colored straw is preferred. Periods of wet weather darken the color. The culms, while flat and about three-eighths inch wide during growth, curl upon harvesting. The Florida grass has wider leaves than the Louisiana and Missouri grasses and has been said to be slightly less wearable. In brooms, used mainly in the northeastern States, it makes up over 50% of the broom surrounded by broomcorn on the outside, and usually sells for about one-third the price of broomcorn. The total production for Florida is approximately 90 freight cars in good years. Before the war a car held ten tons, but during the war cars were loaded to 14 tons.

FIG. 2. A bur of Fuller's teasal, *Dipsacus fullonum*, the ripened flower heads of which have long been used in Europe and America to raise the nap of cloth.

This grass is known in the Florida area as "switch grass", and it may grow mixed with a sedge, *Fimbristylis castanea* (Michx.) Vahl, which may account for 3% of the total production. The sedge is considered to be of better quality than the spartina.

Teasels

Teasels play a generally unappreciated part in the manufacture of many

textile fabrics, for which purpose they are cultivated to form a small but highly specialized agricultural industry. The stiff, needle-like, modified leaf bracts which form below the flowers in the head or bur make the bur of value in textile manufacturing where the needles of the bur are used to raise the "nap" or "pile" of the cloth to produce desired finishes on specific fabrics. The soft warmth of blankets may partly result from such a finish. Before the development of machines and steel pins in combs, the woolen industry dressed all cloth with teasels, but today steel brushes are used for raising the nap on most fabrics. However, teasels have not been entirely discarded, and they are cultivated and produced in Europe and to some extent in this country to serve an essential need. Teasel burs have been stated to be superior to steel combs for very fine cloths and where the nap is raised under damp conditions that may cause steel pins to rust. Steel combs are too rigid and do not have the "give" of the teasels.

The teasel plant, *Dipsacus fullonum* L., is called Fuller's or Draper's teasel. It is not native to the United States but to southern Europe. Rarely is it found growing wild near woolen mills in our eastern States. It differs from the wild, common or card teasel, *Dipsacus sylvestris* Mill., naturalized from Europe and found in many waste areas in the United States, by having hooked scales or spines and not straight ones. The plants are biennial, producing burs or flower heads the next year after the seeds have been planted. The plants the first year are leafy and grow about a foot high, but the second year fruiting, prickly, erect shoots grow up five to seven feet tall. It is upon the ends of these shoots and their lateral branches, which are encouraged, that the burs are formed.

Teasels are cultivated principally in Germany, France, Spain, England and the United States. However, they constitute a relatively minor industry in these countries, and a crop failure in one country would affect the available supplies and prices in other countries. It has been reported that teasels have been raised near the town of Skaneateles, New York, since the year 1840, and in Oregon since 1900. Domestic teasels have to compete in the market with foreign teasels, normally imported from France, and must overcome the inherent tradition in many old mill men that foreign products are superior to our own.

The quality of teasel is measured by its elasticity or "give", weight or size, retention of spines, wearing qualities and brittleness. These characteristics are believed to be greatly influenced by planting seed of a proper variety and by selection of a growing region having favorable soils and climatic conditions. Dry harvest seasons are generally preferred wherever teasels are grown, for such weather insures not only proper maturing of the burs on the plant but curing after harvest. Nature has been credited with curing the burs better than can be achieved by artificial drying. On the other hand, moderate or ample rainfall is desirable during the spring and early summer. Long periods of incessant rains or damp weather cause water to lodge in the bracts of the bur, which creates a weakening if not a rotting of the bur. Variability of the weather results in the quality of the teasels varying from year to year. In general, the climates where teasels are grown in Europe and Oregon are milder than in our northern States. The teasel-growing seasons in the vicinities of Marseilles, France; around Valencia and Alicante, Spain; Somersetshire, England; and to some extent in Oregon are relatively long, which seems to insure maximum development of the burs the second year, differing from the quick growing season due to late winters which are experienced in many northern regions.

Teasels are generally grown on

medium to heavy soils that often are calcareous. In England the soil is described as a rich heavy clay soil. In New York they are cultivated on slopes having heavy soils but soils with adequate drainage. Some are grown upon lighter soils, but such soils may have much silt and available sub-surface moisture, as occurs on the silt bottoms of the Rhone river in France. Soil drainage and freedom from weeds have been stressed by growers.

Fig. 3. Teasels after harvesting are dried in well ventilated barns. They are placed in layers three or four inches deep upon numerous scaffolds.

Planting may be in beds from which the small seedlings are later transplanted to the field. In other cases the seed is planted directly in rows approximately three feet apart which are adapted to cultivation using standard farm equipment. The plants are later thinned in the row to spacings of 10 to 12 inches between plants. If planted in beds the seedlings are later transplanted in rows three feet apart and spaced 10 to 12 inches in the rows. Corn has been recommended for planting in the same row with the teasels the first year. This insures some return the first year and may not be very detrimental to the teasels. The corn at harvest is cut to leave a tall stalk that serves to collect and hold snow to protect the teasel plants from winter killing. In some cases only one-third of the area planned for teasels is sown in rows. The small seedlings thinned out from this planting are sufficient to plant the remaining two-thirds of the field. Approximately one to two pecks of seed are sown per acre. Although a great deal is not known in reference to cultural practices, some growers have preferred to grow teasels after corn or beans. This would result in clean cultivation the previous year to help eliminate weeds from crowding out the small teasel seedlings that follow. Fall wheat can easily follow teasels. The second year the main teasel stems may be cut off two feet above the ground to cause branching to insure greater production of burs.

The burs are harvested by cutting them off, together with three to four inches of the stem. It is usually necessary to go over the field two or three times, or in some cases [illegible] times, because

they ripen unevenly. They are collected in large baskets which when filled may be emptied on large rack-type wagons for hauling to the drying sheds. The drying sheds provide adequate ventilation, as the teasels are spread in thin depths, two to three inches deep, upon numerous racks or scaffolds. Such drying prevents heating and rotting of the burs. A deteriorated bur when placed in contact with cloth might lose its hooks, making it useless. Harvesting should begin as soon as possible after the blossoms have fallen, about the first of August, for at this time seeds at the bottom of the head are almost mature. The harvester needs a sharp knife or shears and wears gloves to protect his hands.

The main stalk produces the largest and strongest teasel, known as the "king", the main terminal branches produce the "queen" teasels of medium size, and the smallest ones growing on secondary branches are called "button" teasels. It is necessary for the producer to sort his teasels and grade them for size in order to satisfy market demands and for the performance of different degrees of work. Considering the climatic and soil restrictions, and the great amount of labor in planting or transplanting the crop, cultivation for two years, hand harvesting several times, the special equipment for drying and sorting and marketing to a small competitive market, the production of teasels is a highly specialized activity that does not attract the average farmer. Those who have grown teasels for many years have been successful, but they have had their lean years, as would be experienced with other crops.

The yield of teasels in some cases is recorded in numbers and in other cases by weight. Each is influenced to some extent by the size of the burs resulting from the variety grown. Yields of 100,000 to 200,000 heads per acre have been reported. The smaller number is for America. In weight the average yield under favorable conditions may vary from 800 to 1,500 pounds of heads per acre.

The price varies in accordance with the demand. When the fashions cause an increased demand for broadcloths there is a correspondingly increased demand for teasels, or if serges and rough woolens are in favor, there is less demand for teasels. Normally the largest producer of a dozen or more growers has cultivated less than a hundred acres of teasels each year in the United States.

The United States Department of Commerce reports that our imports were in 1934, 13,767 pounds of teasels valued at \$4,090; in 1939, 48,962 pounds valued at \$8,610, all from France; and as a result of the war only 1,041 pounds in 1942 valued at \$504, which all came from Argentina.

In use the teasels are arranged on a cylinder in such a way that the cloth passes slowly over them while the cylinder or "gig", as it is called, revolves. Thus the recurved hooks catch the fibers of the cloth, causing them to stand up from the surface to form a nap which may be sheared to bring it to a uniform length. Great care has to be taken in mounting the teasels so they will work uniformly and not produce stripiness by bearing heavier on the fabric at one point than at another. The teasel hook is strong enough for the work and yet elastic enough to "give" before breaking the cloth. Teasels are used for raising the nap on very fine woolen cloth such as broadcloth, high quality overcoating, camelhair topcoats, high quality woolen blankets, billiard cloth, piano cloth and many other industrial fabrics.

One additional use should be mentioned for teasels, as many people are possibly more familiar with the use of them in dry floral wreaths than by woolen manufacturers. Floral teasels are colored for dry wreaths, and the price has been about a third of the price of burs sold to clothing manufacturers.

The Distribution, Abundance and Uses of Wild Drug Plants in Oregon and Southern California

Where the accessibility, prevalence and variety of native medicinal plants may well serve as the basis of an American crude drug industry.

ERNST T. STUHR

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Introduction

NATURE has endowed the Pacific Slope of the United States with unusually favorable climate and soils for plant growth. Throughout this vast region which extends from Mexico to Canada there is an abundance of varied plant life, including a number of important drug plants, some of which are native to the Pacific Coast States and others of which have been introduced there. Some of the native plants abound only in the woods and on the hillsides; others are also under cultivation in certain localities. A few commercial projects in the area have developed into worthwhile proportions, but the Pacific Coast as a whole is still a virgin field from the standpoint of scientific investigation and development of medicinal plant resources. The potential possibilities for a crude drug industry in the area shoul l be unlimited.

Surveys under the auspices of the Committee on Botany and Pharmacognosy of the National Research Council and by chemurgic committees show an impressive list of significant native wild medicinal and allied economically important plants. This article considers only the regions where these surveys have been completed, namely, Oregon and southern California. Similar studies in northern California and the State of Washington are still in progress. A few of the more important plants which thrive in the region covered by the surveys so far, either growing in their native habitats or being cultivated successfully on a commercial basis, are cascara, ginseng, goldenseal, belladonna, peppermint, flax, barberry, juniper and ergot. More specifically, the natural distribution, abundance and uses of these, and preparations of the drugs which they provide, may be listed as follows:

Native Wild Medicinal Plants of Oregon by Counties

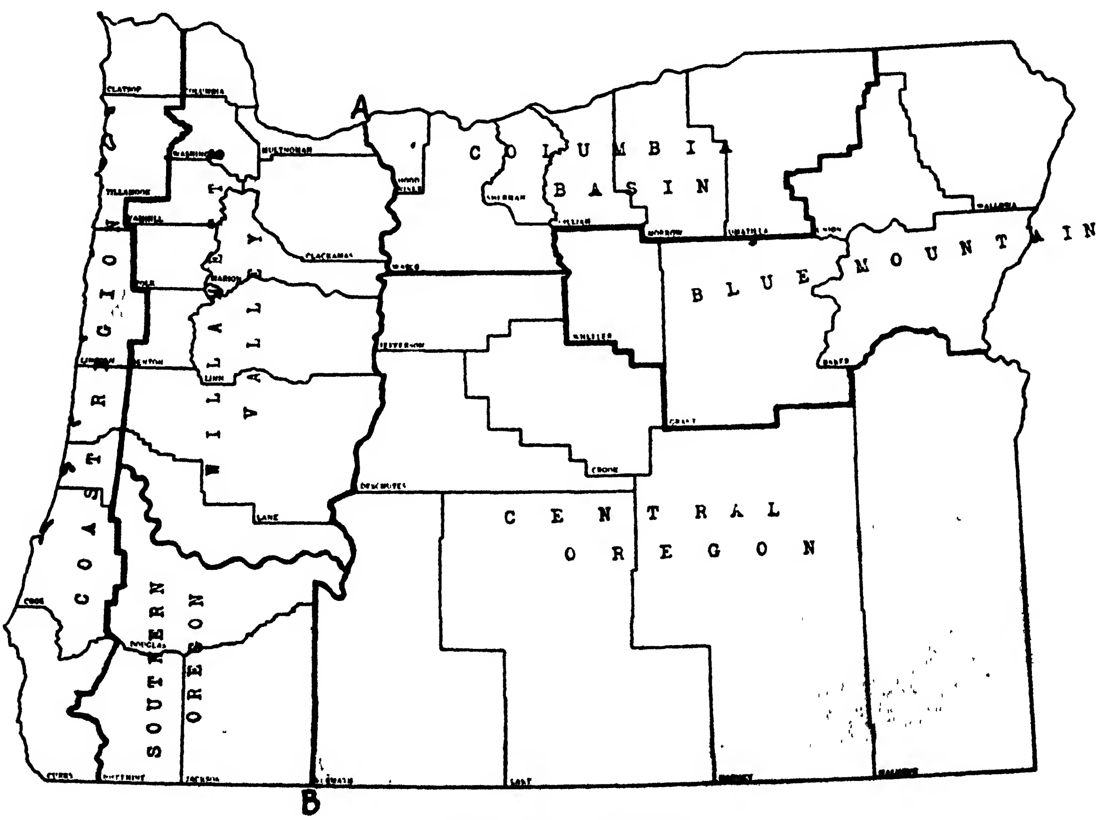
BAKER COUNTY		
Arctostaphylos Uva-ursi (L.) Sprengel	Dry north slopes	Not abundant
Berberis	Most wooded slopes	Not abundant
Chimaphila umbellata (L.) Barton	North slopes, higher elevations	Not abundant
BENTON COUNTY		
Berberis	Wooded slopes	Not abundant
Cytisus scoparius (L.) Link	Waste lands, central to western area	Fairly abundant
Digitalis purpurea L.	Western half of county, woodlands, roadsides	Fairly abundant
Rhamnus Purshiana De Candolle	Throughout foothills of Coast Range	Fairly abundant

CLATSOP COUNTY

Berberis	General over county	Abundant
Cytisus scoparius (L.) Link	Western part of county	Abundant
Digitalis purpurea L.	General over county	Abundant
Rhamnus Purshiana De Candolle	Scattered generally over county, more abundant in eastern part	Quite abundant

COLUMBIA COUNTY

Berberis	Rich woodlands and cut-over lands	Abundant
Cytisus scoparius (L.) Link	Cut-over lands and northern part of county	Abundant
Digitalis purpurea L.	Northern part	Abundant
Rhamnus Purshiana De Candolle	Rich, moist woodlands	Abundant



DIVISIONS OF OREGON

Geographically the State is divided into two divisions, commonly known as Eastern and Western Oregon, indicated by the line AB or Cascade range of mountains. Eastern Oregon has dry summers and cold winters. Western Oregon has temperate summers and mild winters with an abundance of rainfall from October to May.

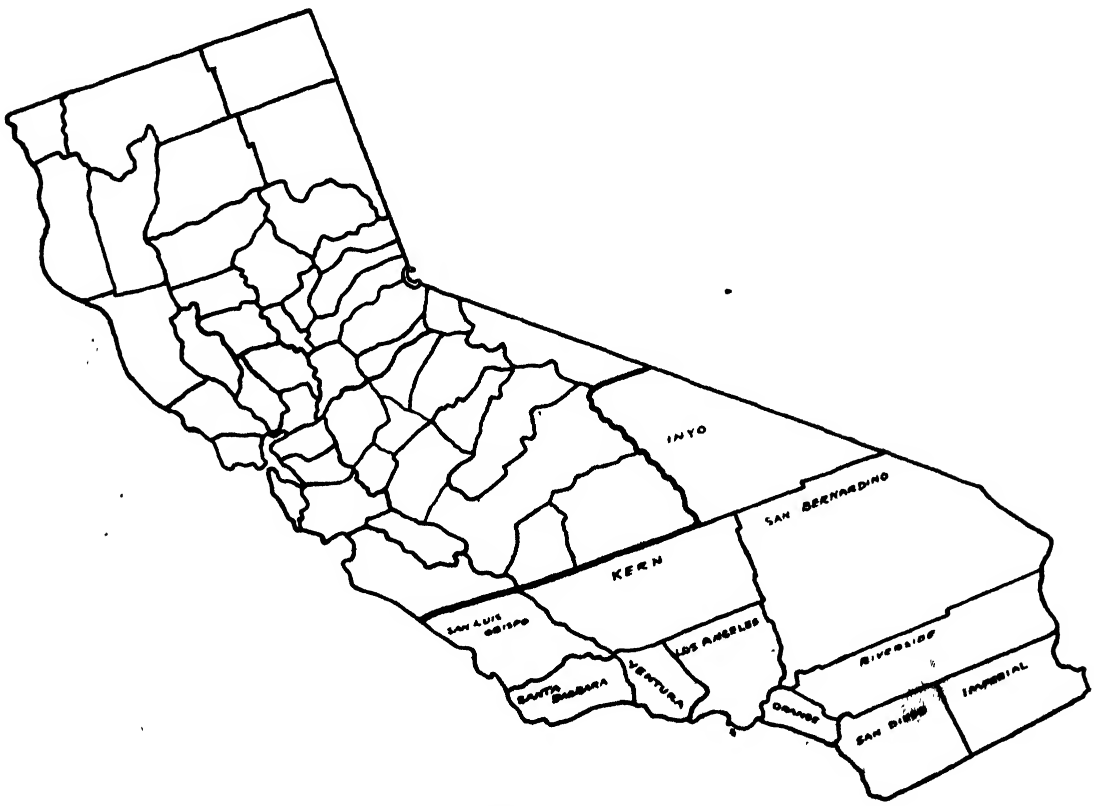
Climatologically the State is sub-divided into six sections: Coast Region, Southern Region, Willamette Valley, Columbia Basin, Blue Mountain Division and Central Oregon.

COOS COUNTY

Berberis	General distribution on higher land	Abundant
Cytisus scoparius (L.) Link	General distribution on sandy and glade land	Fairly abundant
Digitalis purpurea L.	Woodland slopes	Scarce
Rhamnus Purshiana De Candolle	General over county	Abundant

CURRY COUNTY		
Arctostaphylos Uva-ursi (L.) Sprengel	All parts of county; on poorer lands and ridges not capable of producing timber	Very abundant
Berberis	On burnt-over areas and range land	Abundant
Chimaphila umbellata (L.) Barton	Occurs on higher ridges	Not abundant
Cytisus scoparius (L.) Link	Only where introduced as ornamental shrub, spreads to wild state if not controlled	Not abundant
Digitalis purpurea L.	All parts of county, on open and range lands, along roads, rivers, *etc.*	Very abundant
Rhamnus Purshiana De Candolle	Throughout county in all areas of better soil	Abundant
DESCHUTES COUNTY		
Berberis	Dry woods, western part of county	Not abundant
Chimaphila umbellata (L.) Barton	Dry woods, western part of county	Abundant
DOUGLAS COUNTY		
Berberis	In all sections of county	Abundant
Chimaphila umbellata (L.) Barton	Higher elevations on west slope of Cascades	Not abundant
Cytisus scoparius (L.) Link	In coast and Elkton areas	Not abundant
Digitalis purpurea L.	West of Range 8, moist lands, usually found on west slope of coast range	Abundant
Rhamnus Purshiana De Candolle	West of Range 7, moist wood lands, scattered east of Range 8 but not in quantity	Abundant, often localized
GRANT COUNTY		
Arctostaphylos Uva-ursi (L.) Sprengel	Semi-dry, yellow pine woods	Fairly abundant
Berberis	Moist to semi-dry woods	Abundant
Chimaphila umbellata (L.) Barton	In Jack Pine country	Abundant
Rhamnus Purshiana De Candolle	Rich, moist woodlands	Not abundant
HARNEY COUNTY		
Berberis	Small amount scattered over northern end of county	Scarce
JOSEPHINE COUNTY		
Arctostaphylos Uva-ursi (L.) Sprengel	Moist shady woods	Variously scattered, south and west parts
Berberis	Forest along stream banks	Abundant
Chimaphila umbellata (L.) Barton	Forest on high mountain sides and top of peaks	Plentiful in southern and southwestern part; also northern part of county
Digitalis purpurea (L.)	Woods and hillsides	Very few in northern and eastern parts
Rhamnus Purshiana De Candolle	Woods along stream banks	Nearly extinct, few remaining have been peeled or killed
KLAMATH COUNTY		
Berberis	Entire county north and west of Klamath Falls, moist woodlands	Fairly abundant

Apocynum androsaemifolium L.		
Riverside, San Bernardino	At 6,500–9,500 feet, San Bernardino Mts.	Occasional
Apocynum cannabinum L. var. *glaberrimum* DC.		
San Diego, Los Angeles, Riverside	Laguna Mts., Palomar Mts., San Bernardino Mts., San Fernando Valley	Occasional
Aralia californica Wats.		
Riverside, Orange	Shaded cañyons, 2,500–5,000 feet, south face of San Bernardino and San Gabriel Mts., Santa Ana Mts. and northward	Moderately abundant



SOUTHERN CALIFORNIA

The counties in which surveys of wild medicinal plants have been completed.

Arctium Lappa L.		
Riverside	Sparingly naturalized as at Riverside	Not abundant
Arctostaphylos glauca Lindl.		
Western counties	Mountain foothills up to 3,500 feet (sometimes higher); to central California	Abundant
Brassica Kaber (DC) Wheeler		
San Bernardino, Riverside	Claremont, Upland, Moreno, Beaumont, Coachella	Not abundant
Brassica juncea (L.) Czerniaew		
Riverside	San Bernardino Valley	Moderately abundant
Brassica nigra (L.) Koch.		
Western counties	On dry slopes and in valley grain fields	Moderately abundant

Cannabis sativa L. San Diego, San Bernardino	Upland, San Diego	Moderately abundant
Carthamus tinctorius L. Los Angeles	Antelope valley	Not abundant
Centaurea Cyanus L.	Escape from gardens	Not abundant
Chenopodium ambrosioides L. var. *anthelminticum* (L.) Gray Coast counties	Frequent, damp places, western slopes of mountains, into valleys	Abundant
Chimaphila umbellata (L.) Barton, also var. *occidentalis* Blake Riverside, San Bernardino	On dry slopes in shade, at 7,000 to 10,000 feet, San Jacinto Mts. (north fork of Tahquitz Creek, Dark Canyon) and San Bernardino Mts. (Dollar Lake region)	Moderately abundant
Cichorium Intybus L. Los Angeles, San Diego	Low waste places, orchards, vacant lots	Moderately abundant
Conium maculatum L. San Bernardino, Los Angeles	In moist places (San Bernardino, Pasadena, El Monte, Los Angeles, Long Beach)	Not abundant
Coriandrum sativum L. Los Angeles, San Diego	Escapes from gardens (San Diego, Los Angeles, Anaheim)	Occasional
Cornus californica Mey.	Along streams and underbrush of mountain regions, up to 7,000 feet; to central and northern California	Occasional
Cornus glabrata Benth. Riverside, San Diego, Ventura	Rare in So. Calif., Warners Hot Spring, Hemet Valley in San Jacinto Mts., Mt. Pinos, near Gaviota Pass; to northern Calif.	Not abundant
Cornus Nuttallii Aud. San Diego, Riverside, San Bernardino	In damp places in mountains at 4,000–7,000 feet (Cuyamacas, Palomars, Dark Canyon of San Jacinto Mts., San Bernardino Mts., Cascade Canyon in San Gabriel Mts.)	Occasional
Datura Stramonium L. Los Angeles	Santa Monica, Playa del Rey	Occasional
Datura Tatula L., also *D. meteloides* Dunal San Bernardino, Los Angeles	San Bernardino north of Claremont, San Dimas Canyon	Not abundant
Dryopteris Filix-mas (L.) Schott. Riverside	Holcomb valley, San Bernardino Mts.	Not abundant
Eriodicyton californicum (Hook & Arn.) Torr. var *lanatum* Brand. Riverside, San Diego	Mountains along western edge of Colorado Desert, from Santa Rosa Mts. south	Moderately abundant

Euphorbia Lathyrus L.		
Riverside	In damp waste places, San Jose hills, San Antonio Canyon, San Jacinto River	Occasional
Foeniculum vulgare Gaertn.		
Western counties	Waste places in mountain valleys	Moderately abundant
Fremontia californica Torr.		
Riverside, San Bernardino, Kern, Los Angeles	Dry slopes at 3,000–6,000 feet, occasional western edge Colorado Desert and southern slopes San Bernardino and San Gabriel Mts.; more abundant on slopes bordering western half of Mohave Desert; north to central Calif.	Moderately abundant
Fumaria officinalis L.		
San Bernardino, Riverside	Orchard weed, Ontario, Upland, Banning	Occasional
Galium angustifolium Nutt.		
Kern, San Louis Obispo, Santa Barbara	Common on dry slopes and among underbrush, below 6,000 feet, west of the Sierra range to coast	Moderately abundant
Galium Aparine L.		
San Bernardino	On shaded banks below 7,500 feet; on the islands off the coast; occasional on deserts (Providence Mts.)	Occasional
Garrya Fremontii Torr.		
San Diego, Orange	Central Calif., also in Laguna Mts. and Santa Ana Mts.	Not abundant
Grindelia hirsutula Hook & Arn. var. *subintegra* Steyermark		
Ventura	Open hillsides; vicinity of Ojai	Moderately abundant
Grindelia robusta Nutt.		
Orange, Santa Barbara	Clay soil of coastal slopes and flats, and wet places on coastal mesas and low ground, from Orange Co. north to Santa Barbara Co.; around Santa Barbara	Moderately abundant
Grindelia squarrosa (Pursh) Dunal var. *serrulata* (Rydb.) Steyermark		
Los Angeles, Kern	Desert slopes of San Gabriel Mts. and Antelope Valley	Moderately abundant
Hedeoma thymoides Gray		
San Bernardino	Dry slopes at 3,000–5,000 feet in Providence and Clark Mts.	Not abundant
Helianthus annuus L.		
	Common as weed in waste places and old fields	Abundant
Lobelia cardinalis L.		
San Diego, Los Angeles	In boggy places below 6,000 feet	Occasional
Malva sylvestris L.		
San Bernardino	Sparingly escaped from gardens, (Redlands)	Not abundant
Marrubium vulgare L.		
	Common weed in old fields and waste places, throughout state	Moderately abundant
Mentha arvensis L.		
San Bernardino, Riverside, San Diego	Marshy places, San Bernardino, Riverside, Cuyamaca Mts.	Not abundant

Mentha citrata Ehrh. San Bernardino, Riverside	Escaped from gardens, mecca, San Bernardino	Abundant
Mentha piperita L. Los Angeles	In moist places, near Los Angeles; also Bay region	Not abundant
Mentha spicata L. Coast counties	In wet places	Moderately abundant
Nepeta Cataria L. San Bernardino, Riverside, Los Angeles	Waste places in Oak Glen, San Bernardino, Riverside, Claremont	Moderately abundant
Plantago lanceolata L. Coast counties	Weed in lawns and waste places; pest in pastures	Abundant
Plantago major L.	Weed in moist places	Abundant
Portulaca oleracea L.	Weed in low or waste places	Abundant
Prunella vulgaris L.	Naturalized in lawns	Moderately abundant
Rhamnus californica Esch. Riverside	In canyons and washes and in undergrounds, up to 7,000 feet on south slopes of San Bernardino and San Gabriel Mts. through western wet slopes to Mendocino County	Abundant
Rhus glabra L. Riverside	In Chino Canyon, San Jacinto Mts.	Not abundant
Ricinus communis L. San Louis Obispo, Santa Barbara, Ventura	Frequent in waste places, mountain foothills and valleys	Moderately abundant
Rumex Acetosella L. Western counties	Damp grassy places in the mountains and along coast	Abundant
Rumex crispus L. Western counties	Troublesome weed in low waste places	Abundant
Saponaria officinalis L.	Escaped from old gardens, especially in cool damp places	Moderately abundant
Senecio vulgaris L.	Orchard and garden weed, as well as waste places	Abundant
Styrax officinalis L. var. *fulvescens* Munz & Johnson San Diego, San Bernardino, Los Angeles, Santa Barbara	Partly shaded slopes below 5,000 feet in Foster, Mesa Grande, Henshaw Dam, Palomar Mts., Trabuco Canyon; canyon above San Bernardino, Glendale, Santa Ynez Mts.	Occasional
Tamarix gallica L. Los Angeles, San Bernardino, Riverside, Imperial, Inyo	Dunes and in washes, San Gabriel River, Wilmington, Ontario, Furnace Creek (Death Valley), Salton Sea, Thousand Palms	Moderately abundant
Verbascum Thapsus L. San Diego	Moist places, Palomar Mts., throughout state	Abundant

Uses of the Wild Medicinal Plants Listed in the Foregoing Survey

GENUS	PARTS USED	PREPARATIONS	THERAPEUTIC QUALITIES[1]
Acacia	Exudation from stems and branches	Mucilage, infusion	Demulcent, emusifying agent
Achillea	Entire plant	Infusion	Aromatic bitter, diaphoretic
Adiantum	Fronds	Syrup, infusion	Demulcent, stimulant, expectorant
Anethum	Fruit	Oil	Stimulant, aromatic, carminative
Apium	Fruit	Oil	Stimulant, condiment
Apocynum	Tuberous roots	Tincture, liniment	Stimulant to sensory nerves, depressant
Aralia	Rhizomes, roots	Compound syrup	Stimulant, diaphoretic, alterative
Arctium	Root	Fluidextract	Diaphoretic, diuretic, alterative
Arctostaphylos	Leaf	Fluidextract	Diuretic, mild disinfectant to urinary tract
Berberis	Rhizome and roots	Fluidextract	Bitter tonic
Brassica	Seeds	Oil	Rubefacient, counterirritant, stimulant, condiment
Cannabis	Flowering tops	Extract, fluidextract	Cerebral stimulant, analgesic, narcotic, sedative
Carthamus	Florets	Infusion	Diaphoretic, laxative, dye
Centaurea	Entire plant	Infusion	Mild astringent
Chenopodium	Fruits, tops	Oil	Anthelmintic
Chimaphila	Leaf	Fluidextract	Diuretic, astringent, mild disinfectant to urinary tract
Cichorium	Rhizomes, roots	Infusion	Simple bitter, laxative, diuretic
Conium	Unripe fruit	Extract	Motor depressant, anodyne
Coriandrum	Fruit	Oil	Aromatic stimulant, corrective, condiment
Cornus	Root-bark	Fluidextract	Tonic, astringent
Cytisus	Dried tops	Infusion, Sparteine	Diuretic in dropsy, cardiac depressant
Datura	Leaves, flowering tops	Extract fluidextract, tincture	Relax bronchial muscles, asthma, anodyne
Digitalis	Leaves	Tincture, powder	Cardiac stimulant, tonic, diuretic
Dryopteris	Rhizome, stipes	Oleoresin	Taenifuge, anthelmintic
Eriodictyon	Leaves	Fluidextract, aromatic syrup	Expectorant, mask bitter tastes
Euphorbia	Entire plant	Fluidextract, compound Elixir	In asthma preparations
Foeniculum	Fruit	Oil	Stimulant, carminative, galactagogue, condiment
Fremontia	Outer bark, inner bark	Poultice	Demulcent
Fumaria	Leaves, juice	Infusion	Tonic, diuretic, laxative, cholagogue
Galium	Entire plant	Infusion	Diuretic, mild laxative, refrigerant
Garrya	Leaves	Infusion	Tonic, antiperiodic

GENUS	PARTS USED	PREPARATIONS	THERAPEUTIC QUALITIES[1]
Grindelia	Leaves, flowering tops	Fluidextract	Stimulating expectorant in bronchitis
Hedeoma	Leaves, tops	Infusion	Stimulant, carminative, emmenagogue
Helianthus	Flowers, seeds, leaves	Tincture	Bitter tonic, astringent
Lobelia	Leaves, tops	Fluidextract, tincture	Expectorant in asthma and bronchitis
Malva	Leaves	Infusion, tincture	Demulcent, emollient
Marrubium	Leaves, flowering tops	Infusion	Bitter tonic, expectorant
Mentha	Leaf (herb)	Oil	Carminative, flavoring agent
Nepeta	" "	"	"
Plantago	Seed	Mucilage	Demulcent, emollient, laxative
Portulaca	Herb, seeds	Infusion	Mild diuretic
Prunella	Herb	Infusion	Aromatic, astringent, bitter
Rhamnus	Bark	Fluidextract	Tonic, laxative, purgative
Rhus	Fruit	Infusion, gargle	Astringent, refrigerant
Ricinus	Bean (seed)	Castor oil	Purgative, lubricant
Rumex	Rhizome, roots	Fluidextract	Purgative, laxative, stomachic, tonic
Saponaria	Root	Alcoholic solutions	Detergent, discutient
Senecio	Plant (herb)	Fluidextract	Mild astringent, counterirritant, emmenagogue
Styrax	Exudation	Compound tincture	Antiseptic, expectorant
Tamarix	Exudation	Infusion	Laxative
Verbascum	Leaves	Fluidextract	Demulcent, emollient

[1] The therapeutic classes of drugs mentioned in this article represent agents used for the following purposes, according to Youngken's "Textbook of Pharmacognosy" or the "New Standard Dictionary" [Ed.]:

Alterative: to change gradually the nutritive processes and bodily habits to a normal state.
Analgesic: to allay pain by depressing the sensory nerve centers.
Anodyne: to produce relief from pain by action on the sensory nervous system.
Anthelmintic: to expel or kill intestinal worms.
Antiperiodic: to modify or prevent return of malarial fever.
Antiseptic: to inhibit, check the growth of, or kill microorganisms on living tissue.
Astringent: to shrink, blanche wrinkle or harden tissue, diminish secretions and exudates, and coagulate blood.
Carminative: to expel gas and relieve colic.
Cholagogue: to stimulate emptying of the gall bladder and flow of bile into the duodenum.
Condiment: to season or give relish to food.
Corrective: to correct or render more pleasant the action of other remedies, especially purgatives.
Counterirritant: to cause irritation of the part to which it is applied and to draw blood away from a deep seated area.
Demulcent: to soothe and protect mucous membranes.
Depressant: to lessen functional activity.
Detergent: to cleanse morbid parts, as granulating wounds and ulcers.
Diaphoretic: to increase perspiration.
Discutient: to scatter swellings.
Diuretic: to increase flow of urine.
Emmenagogue: to reestablish or increase menstrual flow.
Emollient: to soften and protect the skin.
Expectorant: to cause expulsion of mucous from the respiratory tract.
Galactagogue: to increase lacteal secretion.
Narcotic: to relieve distress and induce sleep.
Refrigerant: to allay thirst and give a sensation of coolness.
Rubefacient: to produce mild irritation accompanied by reddening when applied to the skin.
Sedative: to allay excitement and soothe the system.
Stimulant: to increase functional activity.
Stomachic: to stimulate appetite and gastric secretion.
Taenifuge: to expel tapeworms.
Tonic: to stimulate restoration of tone to muscle tissue.

Drug Plants Under Cultivation on the Pacific Coast

While this article is concerned primarily with the wild sources of medicinal plants in the area covered, a brief account is called for with respect to the attempts so far to bring these plants under cultivation as the beginning of an American crude drug industry.

The importance of the development and the future outlook of such an industry in the region depend to a great extent upon economic conditions in this post-war period. The war has had its influence in stimulating interest in developing native plant resources, and has inspired experimentation with introduced plants from foreign countries. As a rule, these undertakings have been sponsored by or fostered through Experiment Stations, Universities or Colleges, or through cooperative research with the manufacturing industry or the Government. The projects are restricted to tested localities, where some have progressed into thriving undertakings, and they may be briefly surveyed as follows.

In California drug and condiment production has been largely sponsored by the California State Department of Education, the Agricultural College and the California Polytechnic School of San Luis Obispo. The existing condiment crops of the State are mustard, caraway, marjoram, poppy, sage, paprika, sweet basil, thyme, rosemary and summer savory. They are being grown on several thousand acres, and the plantings will probably increase as long as favorable prices prevail. Some other plants, *e.g.*, senna and licorice, have undergone extensive experimentation in southern California. Also, small experimental plots of anise, dill, fennel, coriander, celery, cumin and certain of the mints have been laid out. During the war period approximately 125 acres of pyrethrum were under cultivation.

Commercial development of more native and introduced plants should be worthy of consideration. For instance, eucalyptus, an early introduction to create windbreaks, could undoubtedly be utilized for oil of eucalyptus production, and the castor plant, a horticultural introduction and the source of castor oil, should offer promising adventure for the agriculturist. The drug agar is being commercially obtained from seaweeds and has already become the basis of an industry of considerable size.

Among native wild medicinal plants in the Northwest worthy of attention are cascara, scotchbroom, digitalis, berberis, juniper and ergot, found growing on the range lands of southeastern Oregon. The latest statistics of commercial plantlings of medicinal and allied crops in the State, showing approximate State totals in acreage, are as follows:

Artemisia	20	Ginseng	25
Belladonna	10	Goldenseal	25
Caraway	5	Lavender	1
Cascara	20	Mustard	3000
Coriander	10	Peppermint	4500
Dill	1100	Pyrethrum	60
Flaxseed	2000	Sage	13

In the State of Washington extensive ginseng and goldenseal plantings have been developed, particularly in the Skagit River valley, and production of cascara has also been studied.

Commercial development of the native plant resources in the Pacific Northwest is, however, still in its infancy, but nature has so splendidly prepared the foundation that the region could develop a promising future industry in the production of crude drugs.

Seaweed Resources of North America and Their Utilization[1]

From the coasts of Nova Scotia, Maine, Massachusetts, North Carolina, California and Lower California, seaweeds are harvested that yield agar, algin, carrageenin and iridophycin for industrial use.

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Introduction

For ages, before the advent of white men, the American Indians on the Pacific Coast gathered seaweed for food, and since the latter part of the last century, the Chinese residents in California have also regularly harvested them for the same purpose. On the Massachusetts coast, the collecting of Irish moss has been an established industry for over a century, and for many years East Coast dulse has been sporadically on sale in the markets of Boston, Philadelphia and New York. Utilization of the seaweed resources of North America, therefore, is not a wholly recent matter, but until lately the harvesting and utilization of these marine plants in America were of a rather primitive and sporadic nature. No concerted effort was made to exploit them on an industrial scale, and it took one World War after another to place American seaweed industries on a firm industrial footing. These industries and the natural supplies of seaweeds upon which they are founded, as well as the utilization of those resources, are discussed in this article.

[1] Contribution from the Scripps Institution of Oceanography, New Series, No. 311.

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America's Seaweed Industries

Potash, Acetone, Kelpchar, Iodine.

Shortly before and during World War I there was a serious shortage of potash in the United States, since the supply of this chemical, so vitally important in modern scientific agriculture, at that time came entirely from Germany. Several domestic sources of potash were soon developed, however, through the concerted efforts of the United States Government and of private industry. One of these sources was the California seaweed known as the "giant kelp" (*Macrocystis pyrifera* (Turn.) Ag.). For the duration of World War I, this kelp remained second only to natural brines as a source of American potash. Through a unique fermentation process, acetone and calcium acetate for the manufacture of smokeless powder were also derived from *Macrocystis*. Two other valuable chemical products, iodine and a bleaching carbon known as "kelpchar", were also obtained.

The Pacific kelp industry thus prospered for a few years, with as many as ten factories engaged in the production of potash, acetone, kelpchar and iodine from the California giant kelp. The kelp factory of the Hercules Powder

Company alone handled as much as 24,000 tons of fresh kelp per month. Mechanical harvesters were devised for cutting the kelp, and production of potash and other chemicals was a feat of modern chemical engineering. Thus, under the stimulus of war, utilization of kelp became well established as a modern industry within two or three years. This potash-from-kelp industry was, however, short-lived, and immediately upon cessation of hostilities, all the kelp factories suspended operation. Since then the American potash-from-kelp industry has not been revived; most probably it will never return, since potash, iodine and acetone can now be obtained more cheaply from sources other than seaweeds.

Algin. The Pacific kelp industry, however, came back in other forms in the late 1930's and is now engaged principally in the production of algin. This is a valuable colloidal substance occurring in many brown algae, especially kelps, and is extensively employed in modern food and other industries in America. In recent years the common Atlantic kelps, *Laminaria digitata* Lamour (horsetail kelp) and *L. saccharina* (L.) Lamour (broadleaf kelp), have also been utilized in the manufacture of algin, and today the annual production of algin in America is estimated at two to three million pounds.

Agar. In the recent war there was no longer a shortage of potash or acetone. There was, however, a shortage of another important material, agar, which is vitally needed in public health work. Agar is derived from red seaweeds, chiefly from members of the genus *Gelidium*. Most of it came from Japan prior to the outbreak of war in the Pacific. Although it has been manufactured in the United States since 1919, domestic agar production amounted to only a small percentage of the total American consumption. Until the outbreak of the war, America's agar industry was not successful, principally because of keen Japanese competition and of the high cost of production. The industry greatly expanded, however, during World War II, and there were five factories engaged in producing this vital product during the war. Production at its peak reached 165,954 pounds in one year. At present, however, only three concerns are still active in processing agar. The seaweeds used are agarweed, *Gelidium cartilagineum* (L.) Gaill. from California and Baja California, Mexico, on the Pacific Coast, and *Gracilaria confervoides* (L.) Grev. from Beaufort, North Carolina, on the Atlantic. Other species of *Gelidium*, *e.g.*, *G. arborescens* Gard. and *G. nudifrons* Gard., are employed indiscriminately with the agarweed in agar manufacture. On the Atlantic Coast *Gracilaria foliifera* (Forssk.) Borgs. is similarly used.

Carrageenin. Although the Irish moss industry may claim to be the oldest seeweed industry in America, it is only in recent years that it has been established as a modern industry. Formerly the industry amounted mainly to harvesting and preparing the seaweed *Chondrus crispus* (L.) Stackh. and selling it as a crudely cured and partially bleached "moss". The buyer had to extract the colloid carrageenin by boiling the seaweed in water and straining the solution through cheese cloth. In the late 1930's the industry started to produce carrageenin in the form of a purified dry powder, but production in large quantities was not achieved until the last few years. At present at least four firms are engaged in producing this product and about half a million pounds were prepared in 1945. The 1946 production was expected to reach 800,000 pounds. The "moss" is collected and cured mainly in Massachusetts, Maine and the Canadian Maritime Provinces, and the dried black or bleached "moss" is sent

to Scituate, Mass., Passaic, N. J., or Chicago, Ill., for the extraction and preparation of carrageenin.

Iridophycin. Production of the seaweed colloids or phycocolloids—algin, agar, carrageenin—constitute the three principal seaweed industries in America. Since 1945 one firm has been engaged in the production of a fourth phycocolloid, iridophycin, from *Iridophycus flaccidum* Setch. & Gard. and *I. splendens* Setch & Gard. which are harvested from the California and Oregon coasts. The most important non-colloid product is kelp meal which is either made into kelp tablets for human consumption or mixed with alfalfa and other substances into animal feeds. The California giant kelp, *Macrocystis pyrifera*, and the bladder kelp, *Nereocystis Luetkeana* (Mert.) Post. & Rupr., are both used for this purpose.

Food. During World War II, the leafy parts of the bladder kelp were harvested and dried to serve for food among Oriental residents, especially the Japanese in relocation centers, as a substitute for the Japanese kombu, *Laminaria japonica* Aresch., then unavailable because of the war. Both laver and dulse are still being harvested for human consumption.

Figure 1 is a systematic arrangement of the useful American seaweeds and their products in recent years.

America's Seaweed Resources

America's resources of useful seaweeds may be grouped, as indicated in the accompanying diagram, into kelps, agarophytes, carrageens, and other red seaweeds.

Kelps. The most valuable seaweed resource in America is undoubtedly the great abundance of kelps. It is not inappropriate, therefore, to remark on the origin and usage of the term "kelp". In the early part of the eighteenth century it was discovered in Scotland, at a time when there was a great demand for soda ash in the manufacture of soap and glass, that if seaweeds were burned their ash

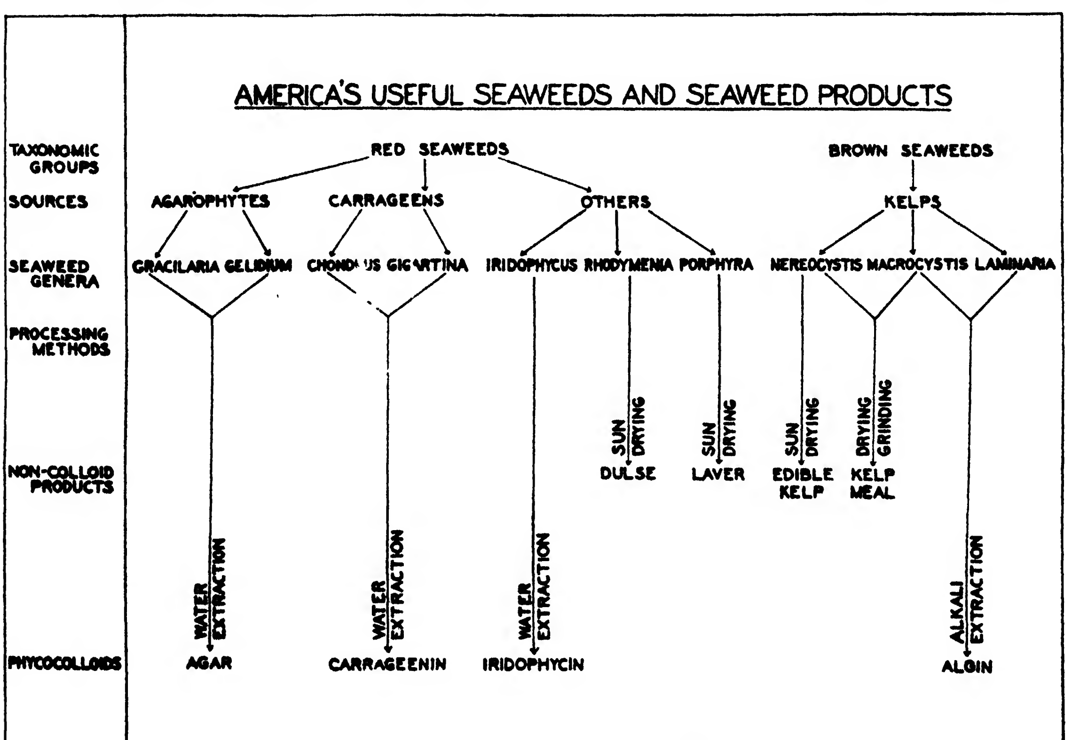

Fig. 1.

was a good source of soda. A seaweed-ash industry was thus born in Scotland and Ireland which was lucrative and important from about 1720 to 1830. To apply to the then valuable seaweed ash, a word of unknown origin, "kelp" was used. In the British Isles the meaning of this word has remained unchanged. The first application of the word to seaweeds themselves, rather than to the ash, appears to have been to an edible New Zealand seaweed called "Bull Kelp" which "has a thick stem, and flat oval-shaped leaf, and is about the thickness of sole-leather". Later this kelp was identified with *Laminaria potatorum* Lamour, a synonym of *Durvillea antarctica* (Cham.) Hariot. When the word "kelp" became known in America in the latter part of the last century, it was applied to certain large brown seaweeds, and *Nereocystis Luetkeana* of the Pacific Coast became "giant kelp", which term was later also applied to *Macrocystis pyrifera* and two others. Eventually they were merely called "kelp". As it is used among botanists nowadays, "kelp" refers to all members of the brown algal order Laminariales with large, flat, leaf-like fronds, although occasionally one finds the word loosely and erroneously used in application to seaweeds generally.

Four species of kelp are utilized in America, two giant kelps on the Pacific and two smaller kelps on the Atlantic seaboard. Among them the most important is undoubtedly the California giant kelp, *Macrocystis pyrifera*.

FIG. 2. Three American kelps of commercial importance. The broadleaf kelp (*Laminaria saccharina*) and the horsetail kelp (*L. digitata*), at the left and center, are both found along the East Coast, available in commercial quantities north of Cape Cod. At the right is a very young plant of the California giant kelp (*Macrocystis pyrifera*) which forms extensive beds from Cedros Island, Mexico, to Point Conception, California. These three kelps are the American sources of algin, used in a variety of ways described in this article. (*Courtesy of Dr. William Randolph Taylor, of the Scientific Monthly and of the Journal of The New York Botanical Garden.*)

Macrocystis. While there are two species of *Macrocystis* on the American Pacific Coast, *M. pyrifera* is the only one commercially utilized in the algin and kelp meal industries, the other species being available only in small quantities. The former is a truly "giant" kelp, and is undoubtedly the largest seaweed

known. While it has been reported by earlier authors to attain the enormous length of 1,000 feet, on the American Pacific Coast the largest plant ever actually measured and recorded was about 140 feet long. A perennial plant, it grows on rocky bottoms free from shifting sand, 25 to 90 feet below the water surface. It grows best in places where there is a continuous swell; and where environmental conditions are favorable, it forms extensive beds from a few hundred yards to two or three miles wide and several miles long. From Cedros Island, Baja California, in the south, to Point Conception, California, in the north, it is practically the only constituent of the kelp beds. Northward it is a minor component of the beds along the coast from central California to southeastern Alaska.

This giant kelp attaches itself to rocks by means of a large conical holdfast, composed of long, densely compacted, branched haptera. It has a stipe which is usually four or five times forked near the base. The branches of the stipe bear blades unilaterally at regular intervals. New lateral blades are formed by asymmetrical splitting of the terminal blade from base to apex. Each mature lateral blade has a short stalk, and a subglobose to spindle-shaped basal pneumatocyst or air bladder. The blade is lanceolate, undivided, up to 80 cm. long and 40 cm. broad, and has an irregularly corrugated surface with denticulate margins.

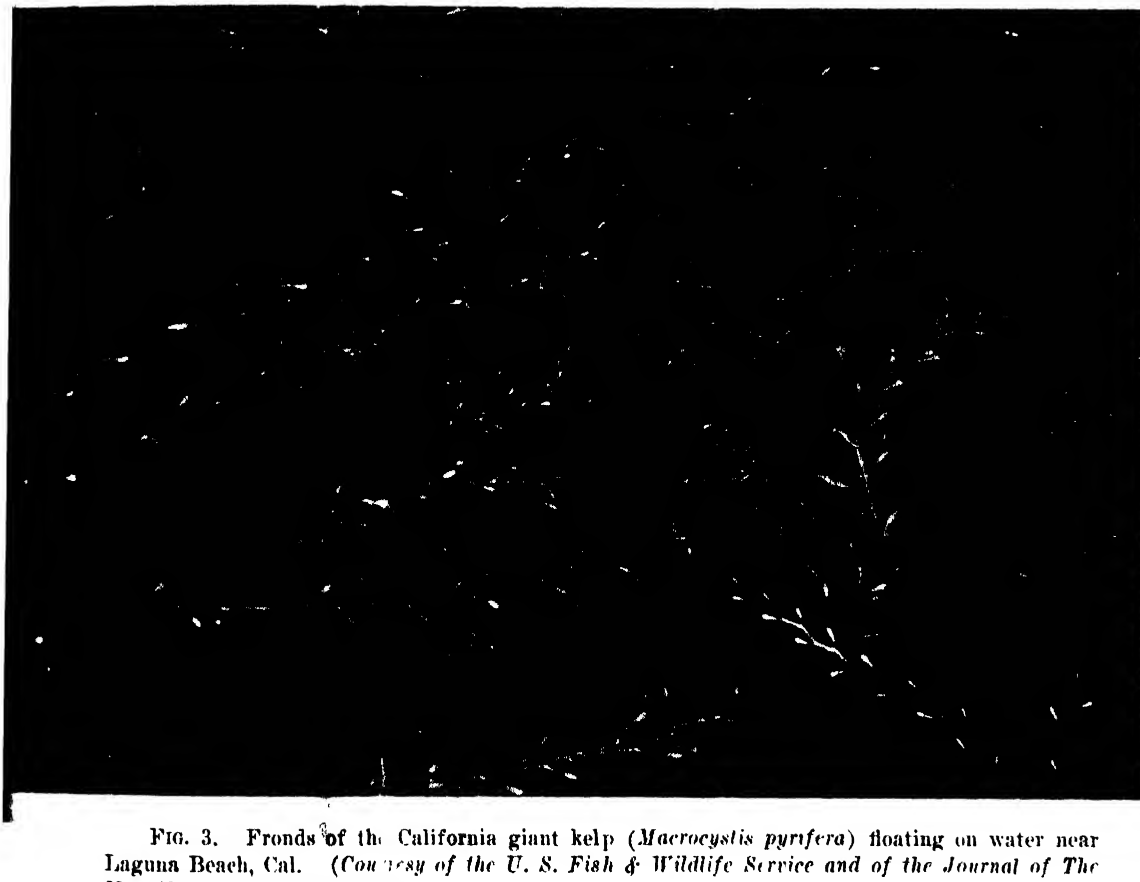

FIG. 3. Fronds of the California giant kelp (*Macrocystis pyrifera*) floating on water near Laguna Beach, Cal. (*Courtesy of the U. S. Fish & Wildlife Service and of the Journal of The New York Botanical Garden.*)

In the early days of the American kelp industry macrocystis was gathered from the beach where it was washed ashore, or whole clumps destructively pulled up by means of a cabl nd hoist; or the fronds

were dragged into a skiff with a hook and cut off with a long knife. All these methods required too much labor and were too inefficient for an American industry to be successful. The mechanical harvester which was later devised solved the labor problem and contributed greatly to the success of the Pacific kelp industry.

A mechanical kelp harvester is a motor-run barge equipped with a modified mowing machine, having a horizontal cutting blade at a depth of about four feet and an endless chain elevator which hoists the kelp on board. The harvesting machine is placed in the bow, with the blade cutting directly ahead of the boat. The knife is considerably shorter than the beam of the boat, and is generally 10 to 20 feet wide. The elevator is as broad as the swath. Its lower sprocket wheels are immediately back of the cutter bar, and it is driven at rather high speed, so as to pick up the cut kelp before the waves wash it away. A knife at each side of the elevator, and parallel with it, serves as an edging device to cut the kelp clear at the sides. Such a barge can harvest and carry as much as 300 tons in a single load. Harvesting is carried out in calm weather throughout the year. By cutting the beds in rotation, they can be periodically worked, and a sustained yield is assured.

FIG. 4. A kelp harvester of the Hercules Powder Company during World War I. (*Courtesy of the Hercules Powder Company.*)

There are no figures available as to the cost of harvesting the giant kelp, since kelp firms operate their own harvesters and do not purchase help from outside sources. Estimates have been placed between two and five dollars per ton of fresh kelp.

Nereocystis. Of the three other giant kelps, *Nereocystis Luetkeana*, the bladder kelp, also known as the "ribbon kelp", is the only one commercially exploited, although to a much less extent than macrocystis. Although an annual, nereocystis grows to gigantic size within a year, plants over 100 feet long being reported, and forms extensive beds like those of macrocystis. The plant has a hemispherical holdfast consisting of densely compacted branched haptera, and an elongated, subcylindrical stipe, gradually broadening upward and terminating in a subglobose pneumatocyst, the apex of which bears four short flattened four or five times dichotomous branches. These bear 32 to 64 long linear undivided smooth blades which may be over ten feet long and one foot broad.

It has been reported that mechanical technique was used in cutting the nereocystis in the Puget Sound area during World War I. Utilization of the bladder kelp, however, has never been on a large scale, and it is highly doubtful that mechanical harvesting could be carried out economically on small scale operations. Along the central California coast, at Monterey and other nearby regions, the rather ancient method of reaping the kelp by hand with large scythes from scows has been used.

During World War II, large quantities of this kelp were harvested for food as substitute for the Japanese kombu (*Laminaria japonica*), only the leafy parts of the fronds being utilized. The war-time production was about 100 tons of the dried nereocystis per annum. Being thinner and less tasty than the Japanese kombus, the bladder kelp is con-

sidered inferior in quality, and its production was terminated shortly after cessation of hostilities in the Pacific. Dried leafy parts of the bladder kelp cost about $400 per ton.

Pacific Kelp Beds. Thanks to the extensive surveys of the kelp beds along the Pacific Coast of North America conducted by the United States Department of Agriculture in the years 1911–1913, we have a fairly good knowledge of their approximate size, location and productivity at that time. The following table summarizes the result of this investigation:

Conception the predominant constituent of kelp beds was *Nereocystis,* with *Macrocystis* and *Alaria* in minor quantities. Survey of the coast along southeastern Alaska was incomplete and covered perhaps less than half of the region. Cameron therefore added an additional estimate to allow for the region not surveyed.

The foregoing 1911–1913 estimate of kelp supplies in the Pacific beds was undoubtedly much too high, for later harvestings yielded less than 10% of the estimated amount. There are plentiful kelps growing in places where, for one

TABLE I

AREA AND PRODUCTIVITY OF PACIFIC KELP BEDS
(Compiled from data of Cameron, Crandall, Frye and Rigg, 1915)

Region	Area sq. miles	Fresh kelp tons	Constituents of the beds, %				
			Macrocystis	*Mac. + Ner.*	*Nereocystis*	*Ner. – Ala.*	*Alaria*
1. Cedros Island, Mexico, to San Diego, Calif.	91.36	16,979,800	100				
2. San Diego to Point Conception	97.92	18,195,300	100				
3. Point Conception to Cape Flattery	36.24	4,377,400	17	7	76		
4. Puget Sound	5.00	520,000	Minor		Major		
5. Southeast Alaska	70.78	7,833,000	18		78		4
6. Southeast Alaska (estimated)	70.78	7,833,000					
7. Western Alaska	17.86	3,567,000			55	33	12
Total	389.9	59,305,500					

It is to be noted that this survey included three kinds of giant kelp, namely, *Macrocystis pyrifera, Nereocystis Luetkeana* and *Alaria fistulosa* Post. & Rupr. In the first and second regions the kelp beds consisted practically entirely of macrocystis, with some *Pelagophycus porra* (Leman) Setch. the elk kelp, in scattered groups along the outer edge of the beds. *Macrocystis* being a perennial plant, determination of the yield of such beds was based on two cuttings per annum. North of Point

reason or another, it is not economically practical to harvest them. Actual cutting of macrocystis in the years 1916–1920, between San Diego and Point Conception, showed the highest annual yield at 394,974 tons in 1917, which amount was slightly over 2% of the estimate.

Wohnus in 1942 made a careful survey of the three kelp beds in the region between La Jolla and San Diego, California. He found a considerable decrease in area since the 1911 and 1934 surveys (Table II).

The numbering of the beds is based on the official kelp chart of the California State Fish and Game Commission. According to Wohnus (personal communication), the 1911 figures were obtained by measuring the areas of the kelp beds on the maps prepared by Crandall. The 1934 data were based on the Coast and Geodetic Survey map, in which the outlines of these California coastal kelp beds were indicated. Concerning the general condition of the beds, Wohnus stated that there were definite signs of improvement. Although in some areas, such as beds No. 2 and 3, the plants have not yet regained the extensive growth described in previous surveys, there are a few regions in which kelp is now growing where it had not been reported previously. Wohnus believed that, with care and proper regulation, the supply of kelp can be maintained and the present yield increased.

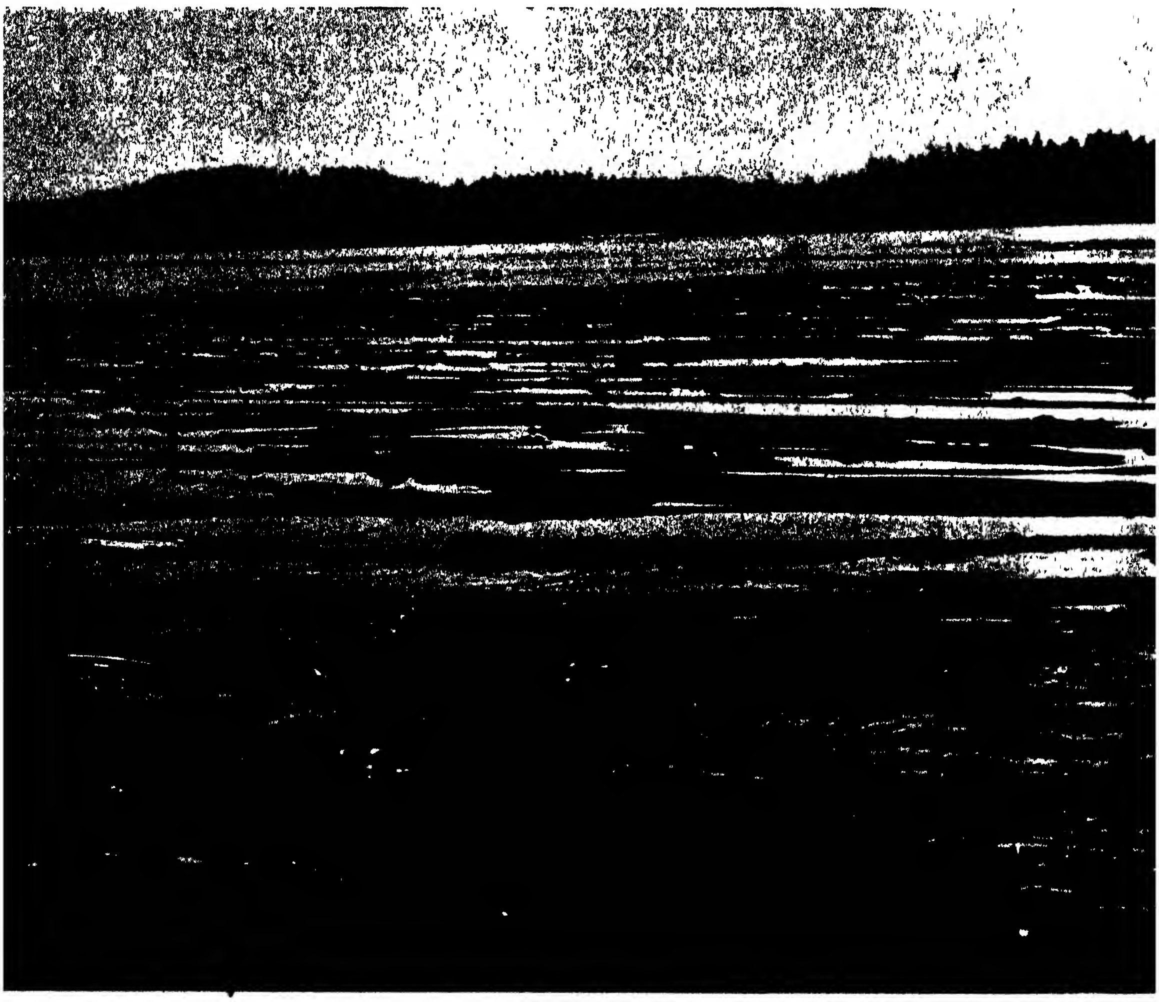

FIG. 5. Fronds of the bull or bladder kelp (*Nereocystis Luetkeana*) floating on the waters of Puget Sound. (*Courtesy of Dr. Robert H. Tschudy and of the Journal of The New York Botanical Garden.*)

Kelp Production in California. Tabulated monthly records of the actual kelp production in California during and immediately after World War I have been published. Large scale harvesting started in August, 1916 and stopped in November, 1918. Commercial cutting of

TABLE II

CHANGES IN AREAS IN STATUTE MILES OF THREE KELP BEDS IN THE LA JOLLA–SAN DIEGO REGION

Bed No.	Year	Area sq. statute miles	Change over 1911 Actual area change	Change over 1911 Per cent of change	Change over 1934 Actual area change	Change over 1934 Per cent of change	Remarks
	1911	1.4					Heavy
2	1934	0.88	−0.52	−37			Scattered
	1941	0.50	−0.90	−66	−0.38	−43	Very thin
	1911	4.08					Heavy
3	1934	2.77	−1.31	−32			
	1941	2.14	−1.94	−47.5	−0.63	−22.7	Thin
	1911	2.1					Heavy
4	1934	2.6	+0.5	+23.8			
	1941	2.5	+0.4	+19	−0.1	−3.8	Medium

the kelp, however, was continued, although on a much smaller scale, for two or three years after the war until all the kelp factories were shut down. The largest annual production was 394,974 tons in 1917.

It should be noted that the production in 1918, namely, 390,863 tons, was only for the period January through October. If kelp was harvested in November and December, proportionally the 1918 production would reach a record high of about 500,000 tons. Since cuttings were made in places more accessible and closer to the operating plants, there were undoubtedly similar quantities of kelps in less accessible places which were not harvested. It is not unreasonable to believe, therefore, that the coastal region between San Diego and Point Conception, with judicial cutting, could produce as much as a million tons per annum, which is slightly more than 5% of the 18,195,300 tons estimated for this region in 1911–1913. On the same basis, the productivity of the Pacific kelp beds may be placed at about three million tons per annum.

TABLE III

MONTHLY RECORDS OF CALIFORNIA KELP PRODUCTION, 1916–1920, IN TONS OF FRESH KELPS

Month	1916	1917	1918	1919	1920
January	1,424	37,100	43,118	1,150	2,136
February	3,310	33,733	24,429	930	1,770
March	3,310	29,995	41,916	1,999	1,970
April	3,310	24,249	43,009	2,101	1,508
May	3,310	41,711	45,838	1,771	2,432
June	3,310	41,631	35,022	877	2,136
July	3,310	24,903	42,084	1,380	2,290
August	37,784	25,612	50,507	1,565	1,955
September	19,135	32,739	35,395	587	2,365
October	10,720	35,522	33,780	1,791	1,950
November	17,757	36,582		1,184	2,668
December	27,857	31,197		1,315	2,284
Total	154,537	394,874	390,863	16,613	25,374

Through the kindness of the California Division of Fish and Game, the writer has obtained monthly records of kelps actually harvested in the last six years by the kelp industry. Cutting of

FIG. 6. Bull or bladder kelp (*Nereocystis Luetkeana*). When dried and ground it is used for making kelp pills for humans and kelp meal for livestock rations. (*Courtesy of Dr. Robert H. Tschudy and of the Journal of The New York Botanical Garden.*)

macrocystis is conducted between San Diego and Point Conception. It is to be noted that the present annual kelp harvest averages about 56,000 tons, or only slightly more than one tenth of that during the peak production years, 1917 and 1918.

Regulations. In California persons engaged in harvesting kelp or other aquatic plants for commercial purposes are required to have a license which costs them ten dollars per year. In addition, there is a privilege tax on kelps and other seaweeds at five cents per ton of wet weights. One may also lease kelp

beds, not exceeding 25 square miles in area, for a period of 15 years, upon payment of $40.00 per square mile. Kelps harvested from leased beds are taxed at three cents per ton of wet weights, in addition to the license and leasing fees.

Laminaria. Two species of kelps are utilized on the Atlantic Coast of North America. They are the broadleaf kelp, *Laminaria saccharina*, and the horsetail kelp, *L. digitata*. Both have a firm holdfast, a distinct stipe and a large broad blade, simple in the former and digitately divided in the latter species. The blades are smooth and yellowish to olive brown and may reach ten feet or more in length. They grow on sublittoral rocks, and occur in commercial quantities from Cape Cod northward. Most of the Atlantic kelps used in the algin industry come from the waters off Nova Scotia. Harvesting is effected with a grapple hauled at a depth of 12 to 15 feet from a power boat, and to a lesser extent by hand dragging or sickling from a dory. The harvesting season extends from June to December.

Laminarias do not float on the surface of the water. Kelp beds consisting of them are therefore not as readily surveyed as the giant kelp beds of the Pacific Coast. There are no data as to the supply and harvest of kelps on the Atlantic Coast. We may obtain some idea, however, as to the amount of kelp harvested on the Atlantic Coast, on the basis of actual alginate production, which amounted to about 300,000 pounds in 1944. Since the two laminarias contain on the average about 4% of algin, on the basis of fresh weight, the minimum annual production of fresh kelp should be at least 4,000 tons, or slightly less than 10% of the current Pacific Coast production. There are reasons to believe, however, that the potential kelp resources of the Atlantic Coast are many times the above estimate.

TABLE IV

MONTHLY RECORDS OF CALIFORNIA KELP PRODUCTION, 1940–1945, IN TONS OF FRESH KELPS

Month	1940	1941	1942	1943	1944	1945
January	1,671	4,417	5,672	3,868	4,256	3,866
February	2,511	2,184	5,967	2,928	2,768	2,990
March	3,231	2,191	6,514	3,683	4,655	3,090
April	3,200	3,281	[illegible]	4,136	4,519	4,372
May	5,007	4,112	5,506	4,920	5,007	5,340
June	6,283	5,281	5,311	5,846	5,963	6,454
July	6,390	7,274	5,715	5,371	5,410	5,882
August	6,142	5,465	5,726	3,240	5,509	5,005
September	5,426	3,337	5,127	2,323	3,667	5,399
October	7,189	6,733	4,417	3,261	5,393	5,863
November	7,063	5,810	3,814	3,978	4,352	6,584
December	4,897	5,632	4,255	4,414	1,536	4,338
Total	59,010	55,717	62,102	47,968	53,035	59,183

There are several species of *Laminaria* which abound on the Pacific Coast, but to date, none has been utilized. Commercial utilization of laminarias, in general, is handicapped by the necessity of harvesting by manual labor, which increases tremendously the cost of the raw material for the industry. If mechanical means could be devised to gather them economically, there is no doubt that the laminaria resources of America could be more thoroughly exploited.

Agarophytes. The two principal agarophytes in America are *Gelidium*

cartilagineum and *Gracilaria confervoides*. The term "agarophyte", originally spelled "agarphyte", was coined by the writer in 1944 to designate red algae utilized in the manufacture of agar, so as to avoid using the term "agar" to apply to both the raw material and the dried extract. Formerly *Gelidium* was the only group used commercially in the American agar industry, but when the discovery of a rich *Gracilaria* resource in the Beaufort, N. C., region was made by Humm in 1942, a new agar industry based on *Gracilaria confervoides* was born on the East Coast.

Gelidium. The "agarweed" of commerce is the maroon or purplish-red Californian *Gelidium cartilagineum* var. *robustum* Gard. This alga is found in commercially harvestable quantities in southern California and Baja California, Mexico, between Point Conception in the north and Magdalena Bay in the south. Although it grows very well in the Monterey region along the central California coast, its growth there is generally sparse and rarely dense enough to warrant commercial gathering.

This plant has a characteristically naked stipe, sometimes as much as seven cm. in length. It is repeatedly pinnately branched and the young branches are typically geniculate, *i.e.*, the outer ends are almost parallel with branches from which they arise. Later the branches, usually opposite but sometimes alternate, straighten and stand at about a 45° angle. The entire plant reminds one of the frond of a fern and is hence sometimes known as "sea-fern". It grows in tufts and attaches itself firmly to the rocky substratum by numerous rhizoidal filaments. While it has been reported by professional harvesters to reach a height of more than five feet, the largest specimens seen by the writer were about four feet tall. The plant is generally considered to be harvestable when one and a half to two feet in height.

FIG. 7. Principal agarophytes used in the American agar industry, the California agarweed (*Gelidium cartilagineum* var. *robustum*, right) and East Coast agarweed (*Gracilaria confervoides*, left). (*Courtesy of U. S. Fish and Wildlife Service and of the Journal of The New York Botanical Garden.*)

Gelidium cartilagineum is typically a sublittoral plant, growing from the lowest spring tide level to a depth of 40 to 50 feet. It does not grow in extensive beds, as does *Macrocystis pyrifera*, but is generally found in comparatively small concentrations, localized on the

tops or at the edges of rocks or boulders in places where the tidal current is strong. Consequently mechanical harvesters for it have not yet been successfully devised, and harvesting has to be effected by raking or by diving and hand-picking. Raking is, however, rarely employed, and is possible only when the water is extremely calm and rather shallow. Before the war some Japanese harvesters who were experienced in raking seaweeds gathered tons of this agarophyte from the San Pedro breakwater. The majority of harvesters dive and hand-pick the seaweed, and, with a few exceptions, use a complete diving rig.

An agar diving boat is generally a small fishing boat about 30 feet long, equipped with air compressor and heavy rubber hose to supply air for the diver while he is working under water. The crew consists of three persons, a boat operator, a diver and a life-line tender. The last mentioned takes care of the air-line and the life-line; the latter is a rope with one end tied around the waist of the diver and the other end held tightly by the tender. By signals, as indicated by the number of pulls by the diver on the rope, the line tender knows whether to lift up the harvest or to haul up the diver. While generally there is a single trained diver in a boat, there may be two. In this case they alternate as life-line tender and diver. This system has the advantage of better working efficiency and increases the harvest per diving boat by as much as 50%.

While the general location of commercial quantities of agarweed is known to the divers, they have to hunt for the particular spots where plentiful supplies of the plant are available. Generally speaking, *Gelidium* growths are readily noticeable by experienced divers, because of the presence of the bryozoan *Membranipora* on the older parts of the plants. Experienced agar harvesters have also claimed that wherever one finds the "goldfish" garibaldi (*Hypsypops rubicunda*), one may expect to find good growths of *Gelidium* in the near vicinity.

Since *Gelidium* grows most abundantly around the edges and on the slanting surfaces of rocks and boulders in places where the water is generally turbulent and the water movement fast, the agar diver usually has to crawl from one rock to another, and occasionally grasps the large kelps for support. With one hand he carries a basket made of small ropes; with the other he pulls a bush of the agarophyte from the rocks and puts it into the basket. When he has filled the basket he ties it to his life-line and pulls the rope twice. Upon receiving the signal, the life-line tender hauls up the basketful of agarweed, weighing between 60 and 75 pounds, and lowers an empty one to the diver. When the harvester is tired, he pulls the rope three times, and the vigilant life-line tender quickly pulls him up.

An experienced diver generally works continuously for one to two hours under water. Then he comes up for a short rest. He may dive two or three times a day, working under water for four or five hours. The diving boat usually goes out in the early morning, since the ocean is as a rule quieter in the morning than in the late afternoon. The actual diving hours average about four per day with a single diver and six with two divers on the same boat.

The quantity of agarweed that a diver can gather per trip depends upon his experience, the condition of the sea and the abundance of the *Gelidium* growths. Under the best conditions a diver may pull as much as one and a half tons of fresh agarweed per diving day. For an average diver working under the usual conditions in southern California, however, a harvest of 1,500 pounds of fresh weed per day is considered very satisfactory.

The agarweed thus harvested is spread

on level ground and dried in the sun, but is not washed or bleached, as is done with the Japanese tengusa. In California fresh agarweed is worth about $80, and dry about $350, per ton.

On the Pacific Coast, besides *Gelidium cartilagineum*, other species of *Gelidium* have also been used occasionally in the industry. The name "hair-agar" is generally applied by the agar divers to *Gelidium nudifrons* and sometimes also to *Gelidium arborescens*. These have thin and hair-like filaments, hence the vernacular name. They grow in deep waters, as does the agarweed, although in somewhat more sheltered places. They form bushes about three feet in height, and have to be harvested by diving and hand-picking. While they produce a slightly inferior agar, they are considered satisfactory agar sources. As they do not grow as luxuriantly as the agarweed, they are only occasionally gathered. In the drying field and in the factory they are generally mixed indiscriminately with the agarweed.

Two other species, *Gelidium densum* Gard. and *G. ramuliferum* Gard., have also been reported to be used by the California agar manufacturers, though apparently not in recent years, for the writer has never found any in the California agar firms. While there are several species of *Gelidium* on the Atlantic Coast, they are all too small for industrial use and not available in commercial quantities.

FIG. 8. Drying agarweed (*Gelidium cartilagineum* var. *robustum*) near Newport Beach, Calif. (*Courtesy of U. S. Fish and Wildlife Service.*)

Agarweed Production. Production of agarweed on the Pacific Coast is rather irregular, since diving is a hazardous and tiresome profession, especially diving for agarweed which has to be pulled

from the rocks. Moreover, in places where the agarweed abounds, abalone is also found in large quantities, and experienced divers generally prefer to take up the more remunerative abalone diving. Furthermore, an agar diver can work only six or seven months a year, since it is not feasible, because of heavy ground swells, to work under sea during the winter and spring months. Consequently in California very few people are willing to take up agar diving as a profession. In Baja California, Mexico, the conditions are somewhat better, as agar diving is comparatively a better job than others there. The agarweed also grows more luxuriantly in the Mexican waters, and harvest per work day is higher than in California.

Monthly records of agarweed harvested in southern California from 1942 through 1944 are available through the kindness of the California Division of Fish and Game and are presented in the following table:

TABLE V

MONTHLY AGARWEED PRODUCTION IN SOUTHERN CALIFORNIA, 1942–44, IN POUNDS, WET WEIGHT

Month	1942	1943	1944
January		15,737	1,540
February		200	11,861
March		21,[illegible]98	14,114
April			
May	10,700	2,[illegible]53	12,102
June	46,000	10,[illegible]5	38,869
July	41,000	25,491	106,287
August	29,400	102,880	96,222
September	6,085	21,337	51,515
October	9,243	13,326	125,156
November	30,622	7,462	21,295
December	42,676		3,260
Total	215,726	223,359	482,221

The monthly fluctuation of the harvest does not necessarily reflect upon the abundance of the weed in the various months, since the amounts gathered depend mostly upon the number of divers engaged in the work and the number of days when the sea was calm enough for agar diving. If we take the 1944 figure as a more representative one for normal production of agarweed in southern California, it is equivalent to about 240 tons wet weight, about 80 tons dry weight. Of these, about 27% came from the coast between Newport, Laguna and Dana Point, about 70% from Redondo and Point San Vincente, and the remaining from La Jolla and Point Loma, San Diego, based on figures supplied by The American Agar and Chemical Company, the largest agar producer in America.

The agarweed resource of the southern California waters is undoubtedly many times the 80 tons actually produced in 1944, since harvesting was then limited to only a few places readily accessible to diving boats. Wartime restrictions prevented operations in numerous places. Even in places where agarweed was gathered, probably more gelidium was left than was harvested. There are reasons to believe that southern California, if thoroughly but judiciously exploited, could yield upwards of 500 tons of dry agarweed per anum.

The majority of gelidium used in industry comes from Baja California, Mexico. While data of the Mexican production are not available to the writer at this moment, they can be easily calculated from the actual agar production and from the amount of agarweed harvested in California. The 1943 production of agar in California was 165,954 pounds, and on the average yield of 18 pounds of agar per 100 pounds of dry agarweed, the amount of raw material required will amount to 920,000 pounds or about 460 tons. Since southern California produced in 1943 only 223,359 pounds of wet gelidium, equivalent to about 40 tons, dry weight, the Mexican production should be about 420 tons, or about ten times the California production.

Gracilaria. Of the numerous species of *Gracilaria, G. confervoides* is the species most extensively employed in agar manufacture. It is, however, only in recent years that the value of this species as a commercial source of agar has been duly recognized and well established. It has been used for years in Japan in making agar, but it has always been a secondary source, used merely as a supplementary material. The recent research conducted in America by Humm and in other countries, including Australia and South Africa, has definitely shown that *Gracilaria* has its appropriate place in agar manufacture. Extraction of agar from *Gracilaria* has now passed from the experimental stage to large-scale commercial production in Beaufort, North Carolina, as well as in Australia and South Africa.

This agarophyte has a bushy frond attached by a discoid holdfast to stones, pebbles, shells, *etc.* The plant body is repeatedly divided, alternately branched, with numerous lateral proliferations. The branches are cylindrical throughout, 0.5 to 2.0 mm. in diameter, tapering gradually above and more abruptly below. The plant is dull purplish-red to purplish, grayish or greenish translucent. It grows best in sheltered bays, especially near river estuaries, where the water is shallow, the bottom sandy to somewhat muddy, and the water movement very sluggish. Under good environmental conditions, in most places, it grows five to six feet long in one season. At Beaufort, N. C., loose pieces of *Gracilaria* have been known to increase ten times in weight within two weeks. At Cherry Point, Vancouver, British Columbia, plants 12 feet long are not uncommon.

Fig. 9. Spreading agarweed (*Gracilaria confervoides*) on wire netting erected a few feet above the water surface for sun drying near Beaufort, N. C.

In places where *Gracilaria confervoides* occurs in commercially harvestable quantities, it generally grows and accumulates in great loose masses. Harvesting gracilaria is therefore a very much simpler matter than harvesting *Gelidium cartilagineum.* It may be collected by forking it into small boats or hand-picked when the tide is low enough. The wet gracilaria may be sent directly to the factory for agar processing, or may be dried in the sun on wire nettings, erected a few feet above water. Humm reported that between August 1, 1943, and January 1, 1944, 1,000 to 1,500 tons

of wet gracilaria were gathered in the vicinity of Beaufort, North Carolina. This was estimated to be equivalent to 150,000 to 200,000 pounds of dry gracilaria, or about 75 to 100 tons.

Gracilaria confervoides is a widely distributed, cosmopolitan seaweed, and grows in sheltered shallow bays where the water temperature is considerably raised by solar radiation. It is found extensively, therefore, along both coasts. In Indian River, Florida, a variety of this species grows luxuriantly, forming large mats on the eastern side of the bay. No quantitative data are available, but apparently the quantity available is much more than that in the Beaufort region, or other places that the writer has investigated. *Gracilaria confervoides* is also abundant along the Gulf of Mexico coasts, although no effort has yet been made to determine its production there.

On the Pacific Coast this species forms beds in San Diego Bay at Chula Vista, California. The productive area is, however, relatively small, and this particular bed is probably able to supply about 100 tons of fresh gracilaria per annum, or about 15 tons, dry weight. Because of the lack of extensive shallow sheltered bays in southern California, the writer was unable to locate any other gracilaria beds besides the one at Chula Vista. This species apparently thrives as far north as the east coast of Vancouver Island, British Columbia, where it grows to over 12 feet in length. Growth is rather sparse, however, and commercial exploitation does not appear to be feasible.

Besides *Gracilaria confervoides*, *G. foliifera* is also utilized in agar manufacture in the Beaufort, N. C., region, but is considered inferior to the former in quality. It generally appears in early summer, just before *Gracilaria confervoides*. On the Pacific Coast, another species, *G. Sjostedtii* Kylin, grows in large quantities on rocks on sandy beaches, and might also be utilized in the industry, if extensive beds could be found.

Carrageens. The name "carrageen" is derived from the coastal town of Carragheen in the Irish Free State, and referred originally to the seaweed *Chondrus crispus*, more popularly known as "Irish moss". The term is now also applied to *Gigartina stellata* (Stackh.) Batters which is commonly harvested together with the Irish moss and used for similar purposes. It has been suggested, therefore, to use the term "carrageen" in a generic sense to include both *Chondrus* and *Gigartina*, and to limit "Irish moss" exclusively to the former.

Irish moss. *Chondrus crispus* is a bushy plant with several blades from a disk-like holdfast, generally 8 to 15 cm. tall, forming loose or often dense clumps. It has a slender compressed stalk which expands sharply into the wedge-shaped base, dividing dichotomously into a flabellate blade. The individual segments vary a good deal, some linear-compressed, some narrow band-like, and some broad-membranous, their breadth varying from 2 to 15 cm. The color of the plant ranges from dark red-purple when shaded or growing in deeper waters, to greenish when growing in shallow places.

Irish moss grows throughout the year on rocks, shells or woodwork in tide pools and in the intertidal regions down to 15 feet or more in depth. The usual method of gathering the "moss" is to hand-pick it when the tide recedes, or to rake it from below the water. In America the harvesting method is essentially the same as that of a hundred or so years ago.

A "moss" harvester does not require much equipment. He needs a 12-foot dory, a pair of oars, a rake, some crude fish oil, an anchor and a creel to carry the harvest from the dory to land. The

rake is the only special equipment needed. It consists of a wooden handle, 15 to 20 feet long, and a steel strap, measuring 12 to 15 inches across and having 24 to 28 teeth. The teeth are six to eight inches long, made from quarter-inch, square steel tapered towards the outer end, and set, usually by electric welding, about one-eighth inch apart. The handle is set at an angle of about 75 degrees to the teeth. In harvesting the "moss", the rake is drawn with the teeth parallel to the bottom along the seaweed bed. The stems of the plant slide between the teeth and are held tightly there. The rake is then lifted and the "moss" pulled out and thrown into the dory. When the water is rough some fish oil is poured on the sea to improve visibility, thus helping the harvester to locate the seaweed beds.

Harvesting is conducted about two hours before and after the lowest tide. An average harvester during this period can gather about 400 pounds of wet Irish moss. Under extremely favorable conditions as much as 1,200 pounds can be harvested by a single person in a day. Upon returning to the shore he packs his harvest in the wooden creel and carries it to the drying fields or sells it immediately to the brokers.

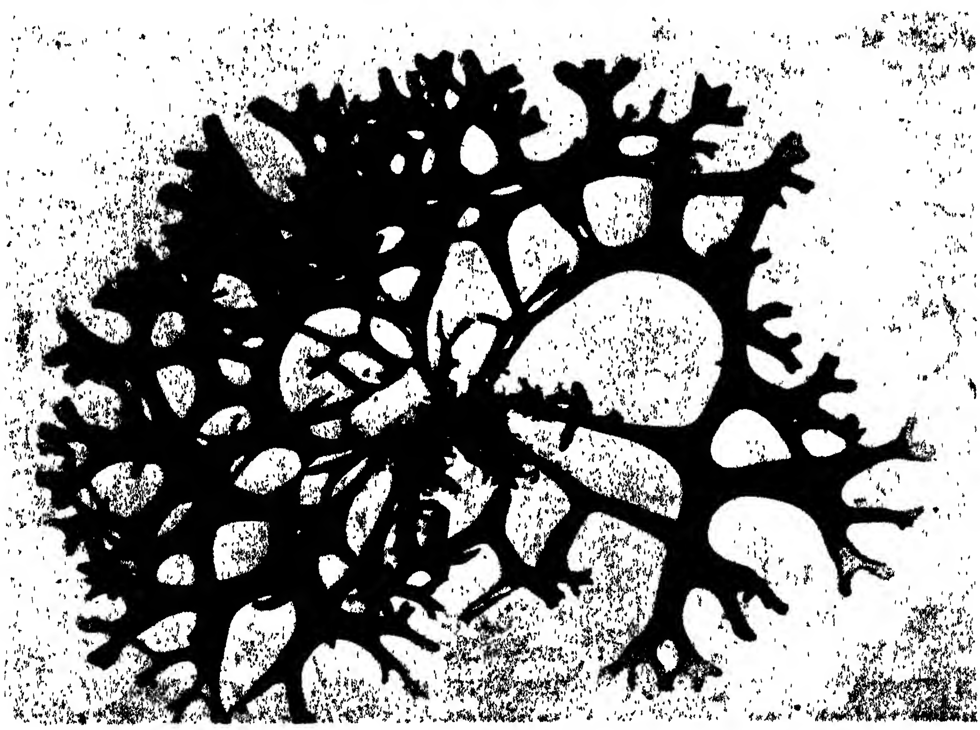

FIG. 10. *Chondrus crispus*, the Irish moss or carrageen of commerce, the collecting of which constitutes the oldest seaweed industry in the United States. For a century it has been harvested and sold, chiefly for making blancmange. Lately, a commercially useful extract, carrageenin, has been prepared from it, to serve as a stabilizer in chocolate milk, salad dressings, soda fountain syrups, cough syrups, tooth paste, hand lotions, and other products. (*Courtesy of Dr. William R. Taylor, of The Scientific Monthly and of the Journal of The New York Botanical Garden.*)

Irish moss should be cleaned and dried as soon as possible to prevent fermentation, which will produce a poor product, and should be thoroughly washed free from shells, stones and the various types of animals accompanying it. Under First Cliff at Scituate, Mass., the operators are equipped with a big tank and two motors for curing the seaweed. One motor controls the continual flow of

water pumped from the ocean which sprays the "moss" in the tank, and the other turns the giant paddles that beat the plant. From the vat the seaweed descends to a picking table of steel mesh that runs as an endless belt. Here the "moss" is separated from the crabs, periwinkles, rock eels, *etc.*, that do not come out in the vat. The cleaned Irish moss is then transported to the drying boards, canvas or wire netting. It is thinly spread, bleached and dried in the sun.

Irish moss is produced in several European countries, especially Ireland, Scotland and France. Before the war most of the carrageen and its extract sold in America came from these three sources. After the war in Europe started, both the United States and Canada accelerated their production which may now exceed the total European output.

On the American Atlantic Coast, although *Chondrus crispus* occurs from New Jersey to Newfoundland, only certain regions have large enough quantities to support commercial harvesting. In the United States, Massachusetts and Maine are the two carrageen-producing states, and Scituate, Mass., is still the center of Irish moss production, which is affording a livelihood for at least 300 local people. Gloucester and Quincy, and to a less extent Lynn and Nahant in the same State, are also producing this seaweed. According to one processor, production of Irish moss in Scituate and nearby regions was expected to reach half a million pounds dry weight in 1946.

Chondrus crispus is reported to be abundant along the entire length of the Maine Coast. Although the Maine Irish moss industry is comparatively young, it is estimated by one processor to have produced two million pounds of the fresh seaweed, or close to 400,000 pounds of the dry plant in 1944. The present annual United States production is estimated by two of the largest producers at about five million pounds of fresh or close to one million pounds of dry Irish moss. Irish moss costs about $40 per ton when fresh and about $400 when dried and bleached.

In Canada the greatest quantity comes from Prince Edward Island and the mainland from the Gut of Canso to Malagash and from Richibucto to Point Escuminac, in the southern part of the Gulf of St. Lawrence. Large quantities also come from the outer coast of Nova Scotia, with good producing grounds in Yarmouth County. The annual Canadian production rose from the prewar 10,000 pounds to 261,000 pounds in 1941, and 2,006,000 pounds dry weight in 1942. The 1943 production was only 877,000 pounds, a figure based on shipment records. One authority believed that over 1,200,000 pounds were actually produced in 1943. The smaller production in this particular year was assumed to be due to the excessively large purchase in 1942, so that buyers were very critical about the quality of the product, and refused to take inferior materials. Current annual production is about two million pounds.

Gigartina. Before the last war in Europe, one carrageenin producer in the United States imported annually for several years about 15 tons of the so-called "Portuguese moss". This consisted of three different seaweeds. "Portuguese moss, wiry type" is *Gigartina acicularis* (Wulf.) Lam., and "Portuguese moss, wide-leaf type" is a mixture of *Chondrus crispus* and *Gigartina stellata.* As the "wiry type" is a more important constituent of the "Portuguese moss", the name should be restricted to *Gigartina acicularis.* This gives a colloid similar to, if not identical with, the Irish moss carrageenin. The Portuguese moss colloid, however, gives a much more viscoid solution than that from Irish moss, and is used for certain special purposes.

Although *Gigartina stellata* is almost as abundant as the Irish moss on the

northern European coasts, this species does not appear to be available in sufficient quantities on the American side of the Atlantic to warrant commercial harvesting. Among commercial samples of American Irish moss, *Gigartina* is indeed a rare component. On the Pacific Coast there are several species of *Gigartina*, one of which, *G. corymbifera* Kuetz., occurs along the central and northern California Coast in sufficiently large quantities for commercial exploitation. It contains a colloid of excellent stabilizing power, probably identical with carrageenin from Irish moss. This seaweed is a broadly membranous form with thick and tough blades reaching two to three feet in length. It grows profusely on rocks at or below low tides, and has to be collected during spring low tides. Collecting is not difficult, however, and the writer once gathered about 80 pounds in about 15 minutes. It is not improbable that *Gigartina corymbifera* may eventually find an appropriate place in America's carrageenin industry.

FIG. 11. *Iridophycus flaccidum*, source of the phycocolloid, iridophycin, a newly introduced colloid in stabilizing chocolate milk. (*Courtesy of the New York Botanical Garden.*)

Other Red Seaweeds. The red seaweeds now used in America besides *Gelidium*, *Gracilaria*, *Chondrus* and *Gigartina* are *Iridophycus*, *Porphyra* and *Rhodymenia*.

Iridophycus. Two species of this genus are utilized, namely, *I. flaccidum* and *I. splendens*. They yield a colloid, iridophycin, which has properties similar to those of carrageenin. Both species have lanceolate or ovate-lanceolate blades with short stipes, arising from disk-shaped holdfasts. The thalli are soft in texture when fresh, turning tough and rubbery when dry. *I. flaccidum* reaches two feet in length and is greenish-olive when growing in the mid-littoral, deep purple in the lower littoral. *I. splendens* reaches four feet in length, generally grows in deeper waters than the former species and is of a rich purple in color. Both grow on rocks somewhat sheltered from the surf. Commercial iridophycus comes from near Crescent City, Pt. Arena, and Jenner in California, and south of Coos Bay in Oregon. Harvesting season extends from June to December. The plants are picked by hand from the rocks at low tide, and during one low tide, lasting

from two to three hours, one man can pick from 200 to 300 pounds of the fresh seaweed in favorable locations. A good picker is known to have gathered as much as 400 pounds in one tide. Much depends on the location, the tide, and especially on conditions of the sea as a result of the velocity and direction of the wind. There are many beaches with excellent growths of *Iridophycus*, but unfortunately they are inaccessible by penses involved in drying, in addition to harvesting cost. There is only one firm engaged in processing iridophycin. It buys the fresh seaweed and takes care of the drying itself.

Porphyra. While most species of *Porphyra* may be utilized as food, the species commonly harvested is the perforated laver, *Porphyra perforata* J. Ag., of California. This forms large, brownish-purple, deeply laciniate, lanceolate to

FIG. 12. Two American food seaweeds, California or purple laver (*Porphyra perforata*, left) and East Coast dulse (*Rhodymenia palmata*, right). Indians of the Pacific Coast relish the laver, and the Chinese use it in their seaweed soup. In eastern metropolitan markets dulse is occasionally on sale, to be eaten raw as a relish. (*Courtesy of the Journal of The New York Botanical Garden.*)

land. Commercial gathering started in the summer of 1944. In 1944 and 1945 about 14 tons of the fresh seaweed were harvested from California and about 16 tons from Oregon. The 1946 production was expected to be over 30 tons. *Iridophycus* dries to about 22% of its weight when freshly harvested. It costs about five cents per pound to gather the fresh weed, or about \$100 per ton. A ton of the sun-dried iridophycus will therefore be worth around \$700, considering ex-

irregularly shaped membranes with deeply ruffled margins. The blades may reach five feet in length, but generally are about two to three feet long. The laver grows on rocks in rather sheltered places from the mid-littoral to the limit of high water. Bonnot reported that 300,000 pounds of dried laver were harvested in 1929 by white men and Indians in northern California and by Chinese in central and southern California. The Chinese harvesters usually come to the

laver grounds in the fall and burn, with driftwood, the rocks on which they expect their laver crop to grow. By early spring these rocks are densely covered with the *Porphyra*. In harvesting, the laver is merely pulled from the rock by hand and is dried in the sun in the form of rectangular sheets. At present, California laver is worth $600–800 per ton.

Rhodymenia. American dulse is *Rhodymenia palmata* (L.) Grev., found along the Atlantic shores from North Carolina northward. Most of it comes from the Canadian Maritime Provinces, especially from the Bay of Fundy, where it grows on rocks in the low littoral and is harvested by hand picking during spring low tides. No data are available as to its production.

Utilization of Seaweed Products

In America, as elsewhere, there have been three stages in the development of the utilization of seaweeds and their products. During the first stage, seaweeds were merely gathered, dried and employed as food or medicine without other processing. In America this started about a century ago with Irish moss as the first seaweed thus utilized. At present we have, besides Irish moss, edible kelp from *Nereocystis*, laver of the West Coast and dulse of the East Coast. Perhaps we should also include kelp meal which is made into stock feeds or tablets for humans. In the second stage of development seaweeds were utilized to supply non-colloid chemicals and had to be processed to yield these products. This started just before World War I, flourished during the war, and came to an end a few years after the war. It was short-lived, but it had reached, within a few years, a stage of glory not matched by even the seaweed industry today. During this period, high grade potassium chloride, acetone, calcium acetate, iodine and decolorizing carbon were produced in large quantities from the California giant gelp, *Macrocystis pyrifera*. At present these materials may be obtained more cheaply from other sources, and seaweeds are no longer used in America as raw materials for non-colloid chemicals. In the third and most recent stage, interest in seaweed utilization has shifted to the seaweed colloids, or phycocolloids. They are extremely valuable as gelling, suspending, emulsifying, thickening and body-producing agents, and have found extensive uses in food, drugs, cosmetics and other industrial products.

Commercial production of seaweed colloids started during World War I, when algin was made at San Diego as a by-product in the kelp industry. Algin, however, did not become the principal kelp product until the late 1920's and early 1930's. Agar, another important colloid, was first made in Tropico (now Glendale), California, in 1920. Although the colloid of Irish moss has been in use for over a century in making blanc-mange in the New England states, it was not until the late 1930's that it began to be produced in the present purified powdered form. Large commercial production of carrageenin actually started in 1942. Iridophycin was made in commercial quantities in 1945; its production at present is still small in comparison with that of the other phycocolloids. Uses of seaweed products in America have been discussed also elsewhere.[1]

1. Commercial Intelligence Jour. **67**: 129, 409. 1942.
   Smithsonian Inst. Rep. **1941**: 401. 1942.
   Fish. Market News **5**(6): 1. 1943.
   Bull. U. S. Bur. Fish. **24**: 167. 1905.
   Jour. Soc. Arts. **10**: 185. 1862.
   Sci. Monthly **58**: 24. 1944.
   Sci. Monthly **59**: 37. 1944.
   Food Industry **17**: 10, 11, 122, 140, 141, 230, 232, 234, 258, 259, 356, 358. 1945.
   Chem. & Met. Eng. **52**(6): 97. 1945.
   Jour. New York Bot. Garden **47**: 1, 32. 1946.
   Phycocolloids: useful seaweed polysaccharides. *In* Jerome Alexander, Colloid chemistry, theoretical and applied. Vol 6. 1946.

Non-Colloids. There are two general groups of non-colloid seaweed products, cured seaweeds and ground seaweeds. Cured seaweeds are sun-dried, sometimes partially bleached, and are used in the form of whole plants. They chiefly serve for food or in making food preparations, and include bladder kelp, laver, dulse and Irish moss. The bladder kelp was used in the last war as a kombu (Japanese kelp) substitute by the Japanese in the United States, and the Chinese use laver extensively in their so-called seaweed soup. Dulse is eaten raw and dry as a kind of salad or relish, or is employed as a thickener in soups, sauces and gravies. Use of Irish moss in the preparation of the well-known blanc mange has been centuries old on the East Coast, and for its preparation the following directions have been given:

"Soak half a cup of dry moss in cold water for five minutes, tie in a cheesecloth bag, place in a double boiler with a quart of milk and cook for half an hour, add half a teaspoonful of salt or less, according to taste; strain, flavor with a teaspoonful of lemon or vanilla extract if desired, and pour into a mold or small cups, which have been wet with cold water; after hardening, eat with sugar and cream."

Stock feed. Ground seaweed is made entirely of kelps, from both macrocystis and nereocystis, hence generally called kelp meal. Its principal use is as stock feed, and analyses of it show the presence of large amounts of various minerals as well as vitamins A, B, F and G. One company produces a meal consisting entirely of dried and ground macrocystis, while another concern uses the same plant but mixes it with fish meal and fish press-water concentrate, fortified with various beneficial substances. There are four kinds on the market under the trade name "Manamer", one for hogs and pigs, one for chickens, one for horses and one for cattle. These are all supplementary feeds to be mixed with grains and other established rations.

The value of seaweeds as stock feeds has been quite well established. Along the coast, the seaweeds may also be used *in toto.* They should, however, be rinsed in fresh water to leach out the excessive salts which, if taken in large quantities, may have an adverse effect on the health of the animals. It has also been found in Europe that animals may require from a few days to a week or more to readjust their food habits from an ordinary ration to a predominantly seaweed diet. The value of seaweeds as stock feed differs with the kind of plant used, with the season of harvesting, with the different animals feeding on them, and with the individual preferences of the animals for the kind offered as food.

Medicinal tablets. Kelp meal from macrocystis is also made into tablets for human consumption to supply mineral salts needed by the human system. There are at least three concerns engaged in this trade. One company at Anacortes, Washington, makes the meal from the bladder kelp in the Puget Sound region, and sends it to New York for processing into kelp tablets. At Vancouver, British Columbia, a new kelp company was recently formed to utilize local kelp resources for similar and other purposes. Kelp meal is also used as a constituent in the diet of hatchery-reared fingerlings at Seattle, Washington, being employed on a basis of 2% of the weight of the ration fed.

Manure. Utilization of seaweeds as manure in America, as elsewhere, has been centuries old. In Rhode Island, for instance, as late as the 1890's, seaweeds formed an important source of farm

Textile Age. 1946.
Nat. Mag. **36**(3): 127. 1943.
Cal. Fish and Game **28**(4): 199. 1942.
Marine products of commerce. 762 pp. 1923.

manure, and in recent years, kelps have been used in various coastal regions as fertilizer. Farmers living at Encinitas, California, gather the drifted kelps on the beach to fertilize their avocado orchards. One chief obstacle in using whole seaweeds as manure is the bulkiness of such materials which contain more than 95% of water. Since the drying and grinding processes do not decrease the value of kelps as fertilizer, use of kelp meal eliminates this trouble. It is expected that kelp meal may eventually be marketed as regular manure for special types of crops.

Colloids. As already mentioned, there are produced in America, at present, four kinds of phycocolloids, namely, algin, agar, carageenin and iridophycin. Of these, algin comes from the brown seaweeds, the other two from red seaweeds.

Algin. The term "algin" generally refers to the sodium salt of alginic acid, a polyuronic acid composed entirely of *d*-mannuronic anhydride residues. Like the other seaweed colloids of commerce, algin is useful wherever a hydrophilic colloid possessing marked gelling, suspending, emulsifying, thickening and water-holding properties is required. Unlike the other phycocolloids, it is chemically active, reacting readily with various metallic salts and acids. Consequently, in certain respects, its uses are limited, while in others it serves especially well by virtue of its reactivity. For example, many of the present industrial uses of algin are based on the fact that addition of a calcium salt to an algin solution produces an immediate precipitate of gelatinous calcium alginate. Thus, by the controlled release of calcium ions, through the use of a relatively insoluble calcium salt, such as calcium citrate, the solutions may be either thickened or converted into rigid gels, in accordance with the amount of the calcium salt added. The rate of the setting of the gel may also be controlled by the introduction of salts, such as a soluble phosphate, which form calcium salts more insoluble in water than calcium alginate.

In the preparation of algin solutions for use in food and other industries, water should be warmed to about 140° F. and the solution should be vigorously stirred. Algin solutions are susceptible to bacterial growth. Therefore, preservatives are commonly added to them if they are to stand for prolonged periods.

The most important use of algin is undoubtedly in stabilizing ice creams, where a colloid is needed to impart smooth body and texture and to prevent formation of large ice crystals during storage. It is prerequisite that such a stabilizer will not in any way mask the flavor of the resulting product. Ice cream mixes made with efficient stabilizers whip fast and produce sufficient overrun. Such ice creams show a smooth clean meltdown without any serum drainage or wheying off. Previously, gelatin was the sole standard ice cream stabilizer, but since algin was introduced about ten years ago, it has been rated by most experts as a better material than gelatin. At least 50% of the factory-made ice creams in the United States are now stabilized with algin.

Some years ago algin was used extensively as a chocolate milk stabilizer. In recent years, however, carrageenin has become the most important agent for this purpose, and while some algin is still being used, it is always employed together with some carrageenin. Until very recently, orange and lemon ices have been stabilized almost exclusively with gums, but algin is now successfully used for the same purpose. It also fills the role more satisfactorily in stabilizing sherbets, where the more costly agar, which required a higher temperature to dissolve, was previously used. To reduce serum drainage, algin is put

into cream cheese and cheese spreads and also whipping creams for decorating fancy cakes. It also serves as a gelling agent in milk puddings by virtue of its reaction with calcium in the milk. Algin is also employed in many different ways in food preparations, such as jellies, jams, icing, meringues, fillings, milk powders, oleomargarines, candies, fruit juice powder and sausage casings.

Algin is useful also in pharmaceutical preparations, emulsifying the petrolatum base, for instance, in making sulfanilamide ointments for surface wounds. It serves as a constituent in pills and tablets, and is also used occasionally in emulsions to carry medicinals such as vitamins. In the cosmetic industry algin is now considered to be one of the most useful colloids, its value residing in its ability to produce standard preparations of controllable consistency, which are transparent, water-white and almost odorless. Ordinary preparations made with karaya gums, for instance, have a grayish-brown color, and those made with tragacanth are quite opaque. Another advantage of algin preparations is the wide range of controllable viscosity, effected by the addition of calcium ions to sodium alginate solutions. The preparations may either be thickened to creams or converted into jellies, depending on the amount of the calcium salt added. It is an excellent vehicle for hand lotions of the saponified type, and a valuable base for tooth pastes and for greaseless, water-soluble ointments and lubricating jellies, replacing tragacanth and other gums, because it is compatible with most of the ingredients in the official formulas.

Sodium and ammonium alginates are both used extensively in the preparation of vehicles for resin emulsion paints, the algin serving as an emulsifier. Algin dissolves shellac to form a lacquer which dries to a tough, tenacious film. Treatment with dilute acids or calcium chloride solution renders this film insoluble, hence useful as a water-proof varnish. Coated over asphalt paints for steel plates and insulated wires, algin helps to prevent the painted surfaces from adhering to each other. During the last war, algin was used as a stabilizer for camouflage paints. Copper alginate serves as a dressing for canvas and burlaps to prevent mildew. Algin is used in the preparation of a new type of fire-retarding compound, recently developed at the United States Forest Products Laboratory. This consists of finely ground fire-retarding chemicals dissolved and suspended in an aqueous sodium or ammonium alginate solution. Best results are obtained with monoammonium phosphate as the fire-retardant, although a mixture of borax and boric acid also gives satisfactory results.

In dentistry algin serves as a dental impression material. Algin-based preparations do not produce as accurate molds as do the traditional agar-based ones. They are, however, more convenient to use and are therefore extensively employed by dentists for general work. Recently ammonium alginate has been adopted for coating dentures made of acrylic resin to take the place of tinfoil which has not been available for this purpose because of the war. Two coatings of the alginate solution are applied with a brush to the gypsum molds when these are still warm from the wax removal. When dry they are immersed in calcium chloride solution, thus converted *in situ* into insoluble calcium alginate coatings. Use of algin in coating dentures is easy and gives very uniform results, and is expected to continue even when tinfoil comes back in sufficient quantities.

In the rubber industry algin serves as a latex-creaming agent; for this purpose ammonium alginate is used instead of the sodium salt. Algin is also useful in treating boiler water for preventing in-

crustation. It reacts with the calcium salts, forming globular flocculent precipitates; these envelop other sediments to give a soft pasty sludge which can be readily blown out of the boiler at regular intervals. As a sizing material algin has the advantage over starch in that it fills the cloth more completely, is tougher and more elastic. In printing pastes algin is widely used as a thickener. Triethanolamine alginate, an algin derivative, is employed as a coating material for solid surfaces. Incorporated in insecticide sprays, algin activates and greatly reduces the necessary effective chemical. Algin is also employed in the purification of beet juices in sugar manufacture, in oil-well drilling muds to seal off porous formations, as a medium for separating plates in the manufacture of storage batteries, as a binder for printer's ink, in the finishing of leathers, and in the preparation of a color-absorbing material.

Agar. Chemically the sulfuric ester of a linear galactan, agar consists of a long chain of *d*-galactopyranose residues, terminated at the reducing end by one residue of *l*-galactopyranose. It is a valuable colloid principally because of its strongly hydrophilic nature and its high gel-strength quality. It is used where bulk is wanted, or where a suspending, stabilizing, thickening or gelling agent is desired. An important use of agar is as roughage. Being not digestible in human systems, agar, when taken in the form of powder or flake, serves as a bulk-producer. This problem of bulk supply is one that only civilized man, accustomed to highly refined food, has to encounter, and agar flakes successfully take the place of the coarse materials that his ancestors ate normally with every meal. For similar reasons agar is incorporated in certain types of breakfast feeds and special bakery products for victims of constipation.

Because of its moisture-holding ability, agar is extensively used in making fruit cakes. These are generally prepared weeks before they reach the customers, and the addition of agar helps to keep them in good condition for a long period. Agar is used in stabilizing icings, in making chiffon pies, in meringues and fillings. It is employed in making confectionaries, chiefly in jelly candies and marshmallows, and in preparing malted milks and acidophilous milks. It also serves as a thickening and gelling agent in the canning of pickled tongues, poultry and the softer types of meat and fish.

Agar is a constituent of petroleum-agar emulsions. In such preparations, however, it does not serve as a laxative, as the public is led to believe, since it is present in too small a concentration, generally less than 1.5%, to be effective. It serves primarily as an emulsifier and helps to make the preparation easier to take. Agar is employed as a vehicle for lactic acid to combat toxicogenic bacteria in the intestines. An interesting use in medicinal preparations is in the so-called "seal-ins" for pills, a type of coating which regulates the rate of solution of the capsule and consequently the timing of its opening. The agar is added in tiny particles and distributed in the waxy material of the coating. By virtue of its water absorption, agar assists in the release of the coated medicinal preparation in the desired place. Agar is also used in the coatings of certain gentian violet capsules employed in the treatment of infection with *Oxyuris vermicularis*. It is also a constituent in a preparation for the treatment of Coccidioides infection in chickens.

Agar is best known, however, as the standard material in the preparation of solid microbiological culture media, and as such, is an indispensable material in the routine sanitary analyses of water and milk. Its importance in public health work and medical and scientific

research is so significant that during World War II the United States Government had to freeze the available agar supply so that the nation's health would not be impaired by lack of this seaweed colloid. In scientific laboratories agar serves as an embedding medium for microtome sectioning, as a vehicle in the standard *Avena* test for plant growth hormones, and as a coagulant for barium sulfate precipitation. In agriculture agar is useful as an insecticide activator and carrier, and in making coatings for nitrogen bacteria cultures.

Agar is extensively used in prosthetic works. It is the basic material in most dental impression materials. In highly critical works, such as inlays and fixed bridges, agar-based compounds are practically the only materials used. Though agar alone is unsuitable for use in certain photographic materials because of its tendency to stick to gelatin and its insolubility in organic solvents or in alkaline solutions, the esters of agar are soluble in a number of organic solvents and can therefore be employed as coatings or backings for photographic films, from which they may be later removed by means of alkaline solutions. Backings are required to keep the films flat and, to some extent, to carry colored materials for minimizing halation.

In the hot-drawing of tungsten wires for electric lamps a lubricant is necessary. At present the lubricant is an agar gel in which powdered graphite is mechanically held in suspension. Formerly the industry used an expensive material known in the trade as "aqudag", procurable only from limited sources. The agar-based lubricant is not only relatively inexpensive and easily procurable, but also more efficacious. The agar gel is able to hold in suspension larger particles which, within certain ranges of size, provide more complete and uniform protective covering on the exterior of the wire.

Shredded agar has been recommended to be incorporated in small amounts in tobacco to retard excessive evaporation of moisture. In hectograph duplicators, agar is used to make the gelatinous rolls. It is also used in the manufacture of submarine storage batteries.

Carrageenin. Like agar, carrageenin is the sulfuric ester of a galactan. It has additionally, however, a certain percentage of 2-ketogluconic acid. The most important use of carrageenin in America is undoubtedly that of stabilizing chocolate milk. Previous to the introduction of a stabilizer, the chocolate-flavored milk on the market always had a sediment of cocoa particles at the bottom of the bottle. The bottle, therefore, had to be shaken vigorously before the drink was poured. The sediment usually adhered so firmly to the containers that great difficulty was encountered in washing them. Now, with the addition of a small amount of carrageenin, these difficulties are largely eliminated. To make chocolate milk, a chocolate syrup is first prepared. The syrup is made by adding a mixture of cocoa, salt and carrageenin to invert sugar solution at about 190° F., and contains about 0.4% carrageenin. One gallon of this chocolate-flavored syrup is then mixed with 11 gallons of milk, and the mixture pasteurized and finally bottled. The finished product thus contains only 0.04% of the Irish moss extract; yet the cocoa fibers are effectively held in a homogeneous suspension and the butter fat does not rise to the top.

Carrageenin is used in food preparations in similar ways as agar and algin. It is employed extensively in making puddings, cheese spreads, pie fillings, cake frostings, jelly fillings, jams, preserves and candy. In the dairy industry, besides being the principal stabilizer in making chocolate milk, it is also employed in stabilizing ice cream, ices and sherbets, and its use in this respect is

said to be increasing fast. It is used in emulsifying cod-liver oil as well as mineral oil. "Decoction Chondri" prepared from carrageenin is probably the best known phycocolloid pharmaceutical emulsifier. The National Formulary recommends a 3% Irish moss solution for the "Mucilago Chondri," which is used by itself as a demulcent and frequently as a vehicle for other medicaments. When employed as the base of cough medicines, carrageenin is said to give them body and to produce a slight soothing effect. It is reported that in Irish bar-rooms in New York, carrageen is soaked in whisky and the resulting liquor offered to patrons as a cough remedy. Carrageenin is also used as a granulating agent in such preparations as aspirin tablets.

In the cosmetic industry, carrageenin is extensively used as a binder, emulsifier, gel-former and bodying agent. It is a regular ingredient in many tooth pastes, and a thick mucilage is used in deodorant pastes. It serves as the base of sulfonated oil-curling jellies, and is also an ingredient of compact powders and rouges. It is employed in making glycerine jellies for chapped hands, and as vehicles for the saponified type of hand lotions.

During the last war, because of a shortage of agar, one concern made a special carrageenin preparation under the trade name "Carragar" to serve as an agar substitute in the preparation of solid microbiological culture media. This contains additional potassium salts which help the carrageenin to form a firmer gel, approaching agar gel. Normally, carrageenin by itself forms a weak gel, even at high concentrations. The product apparently is quite successful for certain media, but for the standard techniques, the excessive syneresis of Carragar media eventually interferes with the counting of colonies on plates.

Before liquor prohibition in the United States, one of the most important uses of carrageenin was in the fining of beers and ales. In the early stages of beer brewing, the cloudy solution of malt extracts contains insoluble materials and undesirable proteins. These can be removed by natural slow setting or rapid fining with the help of a clarifying agent. Carrageenin has the ability to combine with the tannin of hops to form a gelatinous mass which absorbs the suspended impurities. The resulting flocculent mass is easily removed as a scum. Carrageenin is still being used in the liquor industry as a clarifying agent, although it has been partially replaced by other chemical finings.

Carrageenin imparts to certain types of leather a desirable gloss and stiffness. It is principally used in the finishing of straight grains and grain upper leathers. A solution is brushed on the leather, which is then glazed by rubbing with glass cylinders. This mucilaginous substance smooths and holds down the tiny rough projections on the surface of unfinished leather. In inner soles, carrageenin is used as a filler to impart stiffness and body to them. Its use also helps in the water-proofing of very heavy leather. When used in shoe polish and leather dressing, carrageenin serves to restore the finish to worn, scuffed leather, and one shoe manufacturer in New England alone used to import annually about 12,000 pounds of Irish moss from Ireland solely for leather finishing.

Like algin, carrageenin is extensively employed in making water paints. Casein paints stabilized with it are easily applied and adhere well to the surface while drying. Carrageenin was among the first hydrophilic colloids used in the creaming of rubber latex, although at present ammonium alginate is the only creaming agent from seaweed sources.

Iridophycin. Like agar and carrageenin, iridophycin is a galactan ethereal sulfate, although of a much simpler con-

tant step toward the present industrial usage of acetone-soluble derivatives. As described recently (67):

"Briefly the process consists in swelling the cellulose fiber so that all the hydroxyl groups are available for acetylation. Acetylation is carried out, using acetic acid anhydride and acetic acid with sulfuric acid or some other suitable catalyst. The cellulose is acetylated to the triacetate and an excess of acetic acid is used as a solvent.

"The cellulose acetate thus formed is then deacetylated to the proper acetyl content. It is then precipitated from the acetic acid solution, stabilized (if necessary), washed free from acids and dried.

" . . . In the utilization of cellulose acetate for industrial fibers, in particular, it is necessary to reduce the acetyl value so that the acetate becomes soluble in acetone".

The selection of a "trade name" for these fibers has been described as follows (70):

"For almost the whole of that fifty year period, the several man-made fibers which survived the experimental stage and emerged into a commercial world were called 'artificial silks', a frank declaration of the motive which produced them and of the light in which they were viewed by the textile craftsman and the consumer. About twenty years ago the producers and merchants of these new members of the textile family invented the generic term 'rayon' to replace the term 'artificial silk'. . . . It was a moment of historic textile importance because it first emphasized that these man-made fibers, despite any outward similarity to silk, and despite the natural tendency to use them in imitation of silk, were actually new and destined to stand or fall on their own distinctive properties and values".

Names now used most commonly for man-made textiles, in which plant tissues form the basic raw material, are "artificial silk", "rayon" and "synthetic fabric". Although the suggestion has been made that the term "synthetic" be reserved for fibers such as nylon alone, no decision has been made concerning a general terminology which will be acceptable to those concerned. The term "synthetic" now serves to distinguish, in general, all man-made fibers from native fibers such as cotton, silk and wool. In the present article it applies specifically to the "man-made" textile filaments manufactured from plant cell walls.

Plant Fibers and Synthetic Textiles

It is worthy of particular consideration from both the biological and the industrial standpoints that, from all of the available plant tissues, fibers were chosen as the raw material for rayon manufacture. Seed fibers such as cotton, bast fibers such as flax, and wood fibers such as are obtained from spruce and pine, are all characterized by the formation of unusually thick cell walls. These walls play such an important rôle in determining the physical and chemical properties of the natural fibers that the problems connected with processing for synthetic fiber production have dealt primarily with cell-wall reactions to the reagents, temperatures, and pressures employed.

The substances which are commonly described in cell walls, in general, may be listed briefly as follows:

1. Cellulose { crystalline, amorphous }
2. Hemicelluloses { Pentosans, Galactosans, Mannosans }
3. Pectic Substances { Protopectin, Pectin, Pectates }
4. Lignin
5. Suberin and Cutin
6. Protein, resins, gums, coloring matter, tannin, callose and minerals.

In the cotton fiber, materials from groups 1, 3, 5 and 6 are found. In bast and wood fibers of various types, materials from all groups may occur. In no cell walls are the different constituents likely to be present in complete segregation, and the colloidal mixtures in which they naturally occur render their separation and identification difficult.

Plasticity and Deformability in Native Cell Walls

In the course of the manufacture of synthetic textile filaments, natural plant

fibers lose their identity, and their walls, once tough and resilient, are transformed temporarily into a soft continuous deformable mass. From the view point of industrial processing, this phenomenon may seem to be unique in cellular experience, and the erroneous conclusion may be drawn that living cells are not confronted with the need for such properties as plasticity and deformability.

Cells Without Walls. For more than a century it has been an accepted fact that the protoplast and not the cell wall is the essential part of a cell; that in the phenomenon of growth, the protoplast precedes the cell wall; and that, in fact, the colloidal protoplasm is the stuff from which cell walls are made.

In some cases, for the purpose of maintaining their plasticity and deformability during important periods of their life history, protoplasts dispense with their cell walls. Close examination of fallen tree trunks in a moist woodland often reveals strands of slime mould flowing slowly from the under side to the exposed surface of the log, the protoplasts unencumbered by cell walls. Other types of protoplasts first build heavy cell walls and later emerge from the enclosure to continue their existence in a new locality. Observations of cells such as these serve to emphasize the fact that when there is a demand for the maximum in plasticity and deformability, the cell either has no wall at all or uses a wall only as a place of temporary abode.

Cell Walls and Cell Enlargement. In the process of growth, cells increase in number by division. After cell division has taken place the protoplasts of the daughter cells often enlarge to many times their original volume, and their cell membranes are extended to accommodate the increased surface area.

During this period of division and enlargement, they are known as "meristematic cells", and the region of the plant in which they are located is known as the "meristem". Their cell walls are characterized by plasticity and extensibility, and chemical analyses show that these physical states are associated with certain membrane-building materials. In this connection two authorities observe (84):

"Macrochemical experiments prove the existence of cellulose in the walls of the meristem, but its presence is masked by association with other substances.

"Protein, closely linked to the cellulose, is found by macrochemical experiments to be most probably the substance which prevents the reaction with iodine and sulphuric acid.

"Pectin is present in each case, though not directly linked to the cellulose in the meristem wall of radicle and root.

"The middle lamella in the meristem is never of calcium pectate but is probably a mixture of pectin and protein".

Microscopic and microchemical analyses of meristematic tissues indicate more specifically the relation of the chemical constitution of young cell walls to their observed physical properties. In general, the primary wall is composed of non-cellulosic materials (26), and this portion of the wall, not the cellulose-rich secondary lamellae, plays the active rôle in cell enlargement.

Epidermal cells of the oat coleoptile represent a type in which cellulose is deposited before cell enlargement is completed (28). The enlargement takes place in the original plastic membrane, however, and in the course of wall-elongation the cellulose is separated into hoop-like bands. The doubly refractive cellulose and the non-double-refractive, plastic materials of both the unelongated and the elongated membranes, can be distinguished in polarized light. During a later period of growth these elongated walls are again made more rigid through the deposition of lamellae rich in cellulose between and within these separated doubly refractive bands. Cells of different types thus control their growth economy through the ingenious use of non-cellulosic and cellulosic materials.

Cell Walls of Root Hairs and Cotton Fibers. Root hairs serve as unique examples of the importance of non-cellulosic materials in enlarging cell walls. Each hair is formed through the elongation of a single epidermal cell of the root; its function is the absorption of water and nutrient materials from the soil. This absorption is facilitated by an intimate physical contact between the root hair wall and the soil particles. Plasticity is again at a premium, and, in addition, the cell wall must permit the passage of aqueous solutions without being either dispersed or dissolved by them.

Stier (78) has found that stretching of the wall takes place more readily at the tip of the root hair than along the sides, and that when bursting occurs, the rupture is almost invariably at the tip. Cormack (19) has shown that these localized variations in hydrophilic properties are brought about by a decreasing degree of calcification of the pectic material from the base to the tip of the hair. It follows that the physical properties of root-hair walls are in large measure controlled by the chemical and physical state of the pectic material which they contain. In most root-hair walls cellulose is not found (41); when present it is reported to be in the form of a very thin layer upon the inner surface of the primary wall of calcium pectate (60).

This type of wall composition is shared with primary walls of young cells, in general. These are composed largely of pectic material and protein (26), and cellulose deposition takes place toward the end of the period of cell enlargement, when loss of plasticity is no handicap. Root hairs represent a special group of cells in which wall plasticity is of continued importance, and cellulose formation and deposition rarely take place.

The function of cellulosic and noncellulosic materials in determining the physical properties of native cell walls is brought out even more clearly by a direct comparison of the cotton fiber and the root hair. Both the hair and the fiber arise through the elongation of single cells upon the surfaces of the root and seed, respectively. The primary walls of both are rich in calcium pectate and contain little or no cellulose. In the course of the apical growth, the tips of both hair and fiber are less highly calcified than the lateral walls.

In later stages of development the marked differences between root hairs and cotton fibers appear. The protoplasm of the cotton fiber produces large quantities of cellulose and uses it in the formation of many secondary lamellae; the protoplasm of the root hair produces little cellulose, and in many types it is entirely lacking. The cell wall of the fiber is thick and firm and is not easily deformed; the cell wall of the hair remains more or less plastic and deformable throughout its entire period of existence. In the mature state the cell wall of the fiber contains a very high percentage of cellulose and a low percentage of pectic material, protein and wax (32); the mature root hair resembles, in structure and composition, the primary wall of the fiber.

Examples may be drawn from various parts of the plant kingdom to illustrate the fact that the properties of extreme plasticity and deformability are achieved in the native cell walls by the use of noncellulosic materials; that membranes rich in cellulose are no longer plastic; and that extraordinary procedures are involved in reversing this state of rigidity in a mature cell wall. Industry relies upon more or less drastic chemical and physical processes. The cells themselves usually bring about such reversal through the use of enzymes (17, 12).

These observed properties of fiber cell walls and comparisons with the properties of walls of other plant cells have served as a basis for some phases of the

research dealing with the colloidal behavior of cotton fibers and wood fibers during the manufacture of synthetic textiles. In the experiments attempts have been made to follow the various types of cell wall components through their progressive stages of reaction to reagents used in xanthation, nitration and other types of industrial procedures. The results, in turn, have been used in efforts to correlate the more fundamental aspects of cell wall composition and structure with the properties of fibers in both the processed and unprocessed states.

Molecular and Colloidal Interpretations of Structure and Physical Properties

Variations in experimental results and different interpretations of chemical, physical and microscopic data have left many of the important considerations undecided. The accumulated information has led, in general, to the development of two different viewpoints of the structure of the native cell wall and the relation of wall materials to synthetic products. One interpretation holds that the cellulose molecule is the functional unit which determines the properties of native cell walls as well as their synthetic derivatives. The other, following classical colloidal lines, explains the same properties upon the basis of a heterogeneous chemical system, established through the vital activity of the colloidal protoplasm and persisting in its more general characteristics throughout the "purification" treatments involved in industrial processing. For the purpose of discussion they shall be referred to as the molecular and the colloidal interpretations.

Molecular Interpretations. Sponsler (75) developed in 1926 a conception of native cell wall structure which would account for the known properties upon a molecular basis. He expressed the belief that X-ray diffraction data obtained from plant fibers could be explained by the presence of chains of cellulose unit cells, of indefinite length, thus eliminating the necessity for consideration of the crystalline cellulose micellae (molecular aggregates) of Nägeli (52). Staudinger (76) in 1934, upon the basis of viscosity measurements, likewise postulated the existence of very long molecular chains of cellulose which he believed to be of sufficient size to warrant the name "macromolecule". Others (35) in 1928 had questioned the indefinite length of the cellulose chains, had expressed the opinion that they are comparatively short and that they are arranged in the form of a bundle or a micellar unit. Carothers (13) in 1931 suggested a new type of organization of cellulose chain molecules in the walls of plant fibers in which the long axis of the chains is approximately parallel to the long axis of the fiber, with pronounced overlapping of the ends of the chains.

Thiessen (81) described the new concept in 1938 as follows:

"The cellulose micelle is an ultramicroscopic mixed crystal of cellulose chains, differing in length. Ends of chains project beyond the micelle ends formed by shorter chains (fringed micelle). Because of the shorter filaments interposed in the micelle core, the fringes have such large lateral distances that van der Waal's forces no longer hold them together. For this reason they tend to separate".

This evolution of the molecular conception of cell wall structure is illustrated in Figure 1. Adaptation of the hypothesis to the interpretation of the behavior of both native and synthetic materials was described in 1938 (31):

"A revision of the Nägeli hypothesis of discontinuous cellulose micellae was found to be necessary. Evidence was found of a system of connected cellulose threads or layers. Cellulose, in the form of long, chain-like molecules formed a skeletel framework. The molecular weight and length of the chains are not known. They give a crystalline X-ray pattern but never are seen in crystalline form. They are insoluble in all ordinary chemical solvents, but in reagents which will throw them into a viscous matrix their viscosities show that a fairly close relation

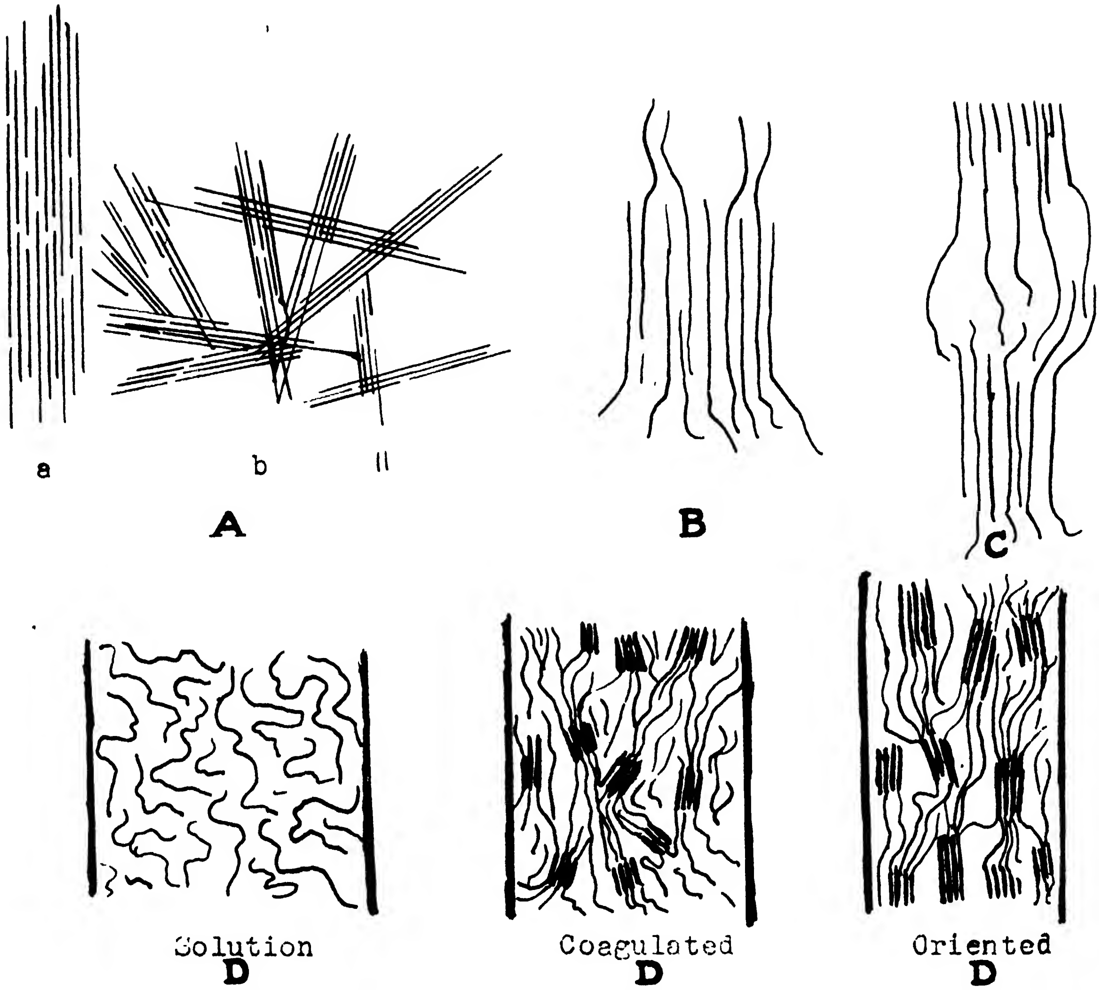

FIG. 1. A. Parallel arrangement of chain molecules (a) and random arrangement of molecular aggregates (b) (*after Carothers*). B. Fringed micelles according to the new theory (*after Kratky*). C. Joining of two micelles by intertwining of fringes through Van der Waal's forces (after *Kratky*). D. Behavior of cellulose chains in a rayon-spinning solution, coagulated and oriented (*after Mark*).

exists between the strength of the whole fiber and the length of the cellulose chain molecules; maximum strength is believed to be reached in chains of about 2,000 glucose residues''.

One of the most recent reviews of this field of research was published in 1943 in the form of a monograph prepared by a staff of specialists under the editorship of Emil Ott (53). The size of the monograph indicates the rapid development of the molecular concept of cell wall structure in the past 20 years. The viewpoint of the treatise is affirmed in the introduction as follows:

''It is the opinion of the editor that the picture of cellulose[1] as a system of long chains of anhydroglucose units is the most important concept in the book. From it may be derived, by the application of ordinary chemical principles, an explanation for almost all the physical and

[1] ''Cellulose'' and ''Chemical cotton'' are used synonomously in the molecular interpretation of cell wall and synthetic fiber properties. Chemical cotton is prepared for industrial purposes from raw cotton linters by first partially removing fragments of stems, seed coats, leaves, *etc.*, by mechanical means, cooking in mild alkaline solutions, bleaching with chlorine, peroxides or other reagents, washing thoroughly and drying. The final product is fibrous and very much whiter than the original unpurified linters.

chemical properties of the molecule. . . . Cellulose tests have been assigned a relatively minor portion of the book because it is felt that this subject is in a quite unsatisfactory state. Most of the tests in common use originated in the days before cellulose chemistry was well understood and have only empirical significance''.

The position now claimed for the molecular interpretation of cell wall structure is evidenced by the following (53):

''On looking backward through the decades from the vantage point of the present, it is easy to see that the chemistry of cellulose remained at a virtual standstill from 1860 to 1920 because ancillary sciences indispensible to the solution of the problem, were in an undeveloped condition. By 1920 the labors of Emil Fischer and other investigations had placed the chemistry of the simple sugars upon a solid foundation. The methylation method of determining the position of hydroxyl groups in the carbon skeleton completed its long apprenticeship, in the hands of Purdie, Irvine, Denham, Woodhouse, and others, about the same time, and the essential, partly methylated glucoses had been prepared and characterized. X-rays gave the first clear diffraction pattern of fibrous cellulose in 1920 and shortly thereafter the colloid chemistry[2] of linear micro-molecules, such as cellulose proved to be, was very greatly clarified by Staudinger and his collaborators. These events make it convenient to choose the year 1919 when Emil Fischer died, as the beginning of the modern period of cellulose chemistry''.

These brief comments and quotations serve to indicate the comprehensive efforts which are being made to interpret the physical properties of cell walls and synthetic materials manufactured from cell walls, upon the basis of the molecular properties of cellulose. As experimental work in this field continues, evidence of more and less highly reactive regions in the wall material has led to a distinction between ''crystalline cellulose'' and ''amorphous cellulose'' (11). In the purification treatments for industrial processing, non-cellulosic materials are considered to have been removed completely, and the factors concerned in the nitration acetylation, xanthation, *etc.*, to be those relating to the effects of processing upon the crystalline and amorphous states of the cellulose alone.

In the course of the development of the molecular interpretation of the structure and physcal properties of cell walls and synthetic textiles, viscosity and X-ray diffraction measurements were originally used as the experimental basis for theoretical considerations (3, 35). The determination of osmotic pressures was brought into extensive usage later for a similar purpose. Calculated values for molecular weights are obtained by means of both techniques. The work in the field of osmotic pressure determinations has been reviewed comprehensively (87). More recently a ''Light-Scattering'' technique has been used extensively. A review of the theory of light scattering has been given (22, 90), and its application to cellulose acetate has also been reported (77).

Colloidal Interpretations. Progress in the field of the colloidal interpretation of cell wall structure and composition has been more or less continuous for more than a century. Lyngbye (45) observed ''minutissime punctata'' in the cell wall of a marine alga in 1819. Valentin (85) and many of his contemporaries found that cell walls increase in thickness by the deposition of material from the protoplasm upon their inner surfaces. In some cells they found microscopically visible granules joined together end to end to form fibrils which, in turn, were deposited as wall material. Others (1, 50) found that the fibrils of the cell wall are separable entities, and that the spiral fibrils do not pass from

[2] The chemistry of ''high-polymers'' or linear ''macromolecules'' is classified by Purves as a branch of colloid chemistry, and a ''colloidal interpretation'' in the sense used here is referred to by Purves as the ''Association Theory''. Experimental developments have thus served to make the borderline less sharp between the ''molecular interpretation'' and the ''colloidal interpretation'', and terms commonly applied to colloidal phenomena are found in discussions of both.

one lamella to another. Schacht (62) showed that fibrils, when arranged in opposite directions in the membrane, have opposite properties in polarized light. The granules and fibrils, with their adhering protoplasmic materials, constitute a typical colloid system. These earlier workers were concerned with the physical rather than the chemical aspects of the system. Between 1840 and 1860 others (*e.g.*, 30, 56) made many contributions to the chemical nature of cell wall materials. They identified "cellulose" and "incrusting substances", which interfered with the chemical reactions of the cellulose, and found that cellulose, nitrogenous materials, minerals and pectic substances can be identified in most cell walls. Nägeli (52), using polarized light for microscopic observations, discounted, in the optical sense, the non-doubly refractive, gelatinous wall material of Fremy and Payen, and concluded that the cell wall is made up of microscopically invisible crystalline "micellae" which are nearly contiguous; that by moistening with water or aqueous fluids the surfaces of these micellae take up water and the previously hard substance becomes soft; and that, upon evaporation, the condition is reversed.

The "Micellar Hypothesis" was popular and the conclusions of Payen and Fremy were frequently overlooked until Mangin (47) published his valuable histological memoires dealing with the heterogeneous chemical nature of cell walls in 1889. Strasburger (79) had found, however, that cell walls, in general, have both solid and gel-like constituents, the latter in the form of a reticular colloidal framework; and that growth in thickness takes place by the deposition of gel and granular "microsomes". Molisch (51) found that the microsomes are connected by fine fibrils of protoplasm, while others (34, 82), in effecting the macrochemical separation of cell membrane constituents, found that the removal of masses of this colloidal gel brings about cell wall disintegration.

Farr and Eckerson (26) in 1934, by means of microchemical analyses and observations in polarized light, determined the cellulose nature of Strasburger's gel-coated microsomes and the non-cellulosic nature of the gel itself. The microsomes were renamed "cellulose particles" and the gel "cementing material" (Figure 2). Others (*e.g.*, 36, 88) have described a similar two-phase structure in cell walls. Wieler compares the relation of the cellulosic and non-cellulosic membrane materials with that of the droplets of honey in the honey-comb to the comb itself. Hess and co-workers (37) have reported that fiber walls are made up mostly of crystalline cellulose surrounded by a thin sheath of other materials which they have named "Hautsubstanz". They have concluded that the recognition of these two fiber components is important for the understanding of fiber structure as well as for reactions to reagents. In both ramie and cotton fibers they have found that the nitrogenous "foreign substance" is frequently held fast during the purification process. Farr and Eckerson (27) have reported that the purified state of cellulose is not approached until the fibrous state is destroyed and the residue is in the form of a fine white powder. This change in physical state they have described as "fiber disintegration," brought about by removal of non-cellulosic cementing material, and not as "cellulose degradation" which would involve changes in the crystalline cellulose itself. These findings have developed into the conception that the fiber wall is made up mostly of particulate crystalline cellulose which diffracts X-rays and is doubly refractive in polarized light, surrounded by a thin sheath of non-cellulosic material which is non-doubly refractive and amorphous. They are not

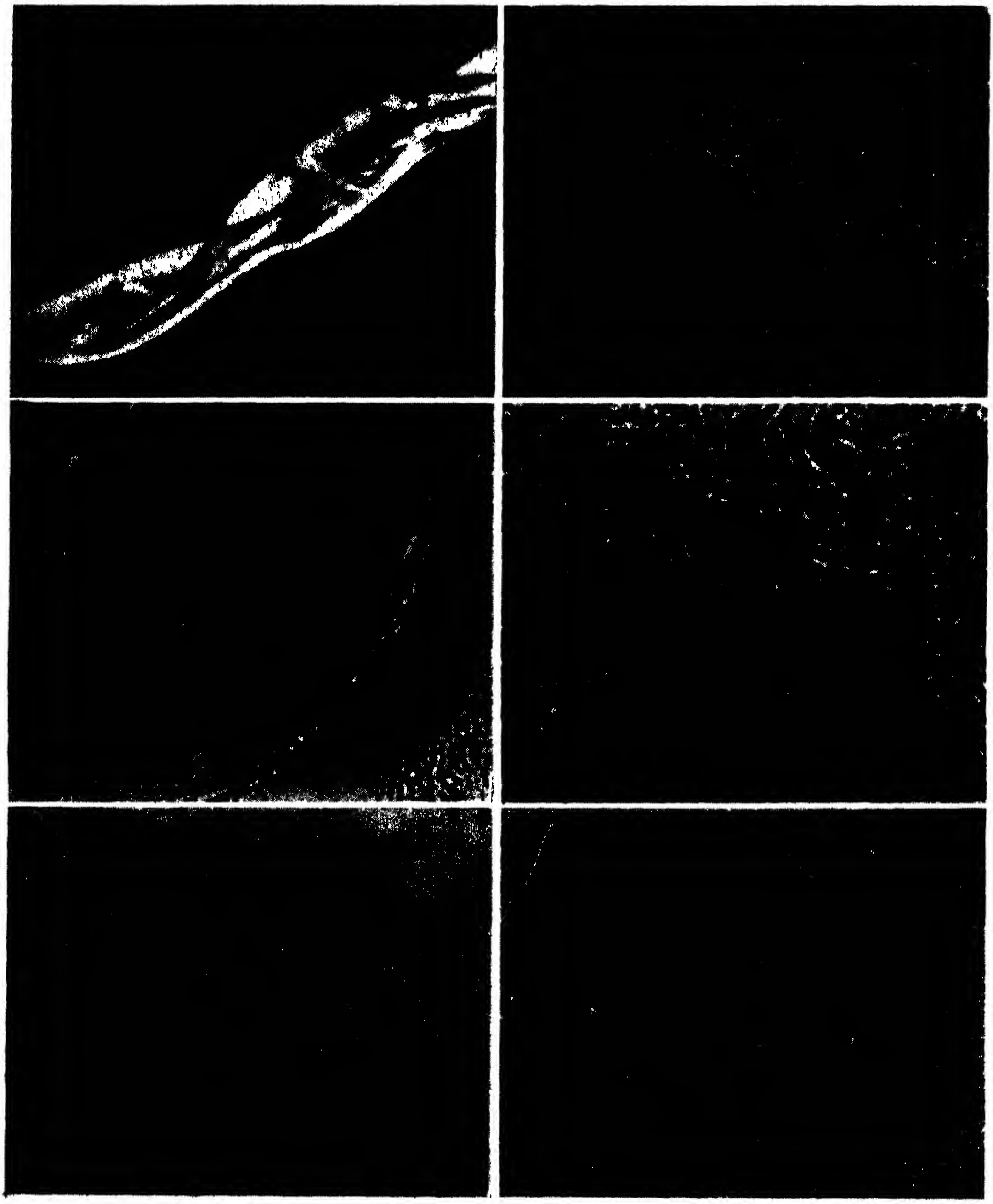

FIG. 2. A (*Upper left*). Single cotton fiber with typical convolutions. B (*Upper right*). Fiber disintegration, showing individual fibrils and cementing material or "Hautsubstanz", ×500. C (*Center left*). Disintegrating fiber washed with solvent for cementing material reveals particulate structure of spiral fibrils. ×700. D (*Center right*). Later stage of fiber and fibril disintegration. ×700. E (*Lower left*). Single fibrils composed of rows of cellulose particles show swelling and blue coloration in sulphuric acid and iodine. ×700. F (*Lower right*). Fibrous pectate prepared according to the method of Baier and Wilson. ×1,380.

in keeping with the conception (7) that the cotton fiber wall is a continuous matrix of cellulose, some portions of which are denser than others, and that the lamellate appearance of the wall is due to alternating zones of dense and less dense cellulose (43).

In 1938 Farr (24) described the colloidal reaction of the cotton fiber wall constituents in cuprammonium hydroxide to be primarily that of the non-cellulosic materials in which the cellulose particles become dispersed. This result is corroborated by some workers (9, 44) but is questioned by others (38, 39) who consider the reaction to be one of the cellulose component of the wall and affirm the value of the measurement of the cuprammonium viscosity of fibrous materials as a basis for determining the molecular weight of cellulose.

In 1939 Compton (18) reported a study of the reactions of cotton fiber wall constituents during the xanthation of fibrous materials. The two-phase structure of the wall was in evidence throughout, and the identity of the cellulose particles was not destroyed during viscose formation.

Farr (25) described in 1941 the microscopic aspects of the synthesis of cellulose in cellulose-forming plastids of living cells. During the period of formation the cellulose is surrounded by a colloidal matrix rich in protein and pectic material, and the final cell wall structure is the result of the organization of these and other protoplasmic components into a continuous, chemically heterogeneous, colloidal system.

Current Trends in the Interpretation of Structure and Properties

Hess (37) has recently confirmed his earlier observations of a primary wall of the native fiber whose structure, composition and texture are different from those of the secondary wall; and for the fibrils of the secondary lamellae, a surrounding-membrane of non-cellulosic material—probably pectin. He reports, in addition, a hitherto unobserved structural element which he has named a "ground fibrilla". Its relation to the other structural elements can be seen from the accompanying table.

STRUCTURAL ELEMENTS	DIAMETER	LENGTH	LIGHT SOURCE
Primary wall	$\sim 0.5\ \mu$		
Lamellae	$\sim 0.2\ \mu$		U. V. $\eta = 2750$ A°
Fibrils	$\sim 0.2\ \mu$		U. V. $\eta = 2750$ A°
Fibril segments	$\sim 0.2\ \mu$	$0.25\ \mu$	U. V. $\eta = 2750$ A°
Ground-fibrillae	80–150 A°	$(0.25\ \mu)$	Electronbeam
Crystalline Micellae	> 60 A°	> 1000 A°	Cu Ka Radiation
Molecule	4.5 A°	Unknown	

The "fibril segments" referred to in this table correspond to the "microscomes" of Strasburger, the "cellulose particles" of Farr and Eckerson and the similar structures described by Wieler in the cells of the "honeycomb". The dimensions as given by these authors are $0.5\ \mu$, $1.1 \times 1.5\ \mu$ and $1.25\ \mu$ respectively. Measurements made in fresh and dried material, unswollen and slightly swollen states, and in different optical systems, may account for these differences. The measurements of fibril segments were made by Hess with an ultraviolet light source. The ground fibrillae, into which the fibril segments separate, were observable only in the electron microscope because of their diminutive size.

The ground fibrillae of Hess do not seem to correspond in their described origin and appearance with the extremely fine fibrillar structures reported in the electron microscopic studies of cell wall materials by others (8, 61, 66). These latter structures have more in com-

mon with the anastamosing fibrils, some of which grade down to and beyond the limits of microscopic visibility, described by Bailey and Kerr.

The chemical nature of these fine anastomosing fibrillae is not decided. The group of authors referred to above, along with Bailey and Kerr, have stated that they are cellulose. Wieler (88) reports similar structures in swelling reactions of many types of cell walls and has found that they represent one of the colloidal states of the continuous phase of the cell wall (honey-comb) in which the cellulose granules are imbedded. Others (6), in a discussion of "fibrous pectates", may have supplied a possible explanation of this finely fibrillar cell wall substance. Figure 2F illustrates a fibrous pectate and its microscopic structure, as observed in ordinary light. As indicated by Wieler, such microscopic phenomena are not uncommon in the manipulation of cell wall materials. Observation of the subdivision of fibril segments into ground fibrillae would require, on the other hand, extremely careful manipulation of wall materials in all stages of preparation for electron microscopic observation. (36).

Hess reports, in addition, that synthetic fibers, beside the well known X-ray structure, have no macromolecular structure which will compare with the ingenious structure of the natural fiber. He considers it likely, however, that in some cases of industrial processing, the "ground-fibrillae" are merely swollen, not broken down, and are again reconstituted in the process of coagulation. These observations, as well as others (18, 24, 44), indicate the necessity for further study of the microscopic structure of synthetic fibers produced from cell walls, at all stages of industrial processing.

Still other workers (23) have contributed a detailed microscopic study of swelling reactions of native fibers in acids and alkalis. From all types of swelling and splitting observed, in which widespread disintegration of the swollen fiber takes place, small uniform-sized ($0.5 \times 1.5\ \mu$) particles were obtained in the form of unswollen residues. In less completely disintegrated fibers these particles are seen with their long axes parallel to the fibril axis, and the authors state that they are probably identical with the "cellulose particles" described by Farr. Continued treatment with hydrolysing agents brings about disappearance of the particles themselves.

The nature and importance of the non-cellulosic constituents of both native cell walls and processed materials has been reflected in a number of recent studies:

Wurz and Swoboda (89), applying quantitative methods for uronic acids to easily parchmentizable and bleached sulfite pulps, found (calcd.) galacturonic acid values of 2.05%–2.5%. Pulps that showed poor parchmentizability contained 1.4%–1.6%, and very poor pulps 0.77%–0.94% galacturonic acid. The authors discount the possibility of the influence of oxycellulose in the pulp. Addition of calcium pectate to a pulp not readily parchmentizable improved its properties.

The non-cellulosic incrustants in the jute fiber resemble, in their behavior, starch-size on a low-twisted, sized, cotton yarn, and while they themselves have little tensile strength, they contribute, in a marked manner, to the strength of the jute by cementing together the ultimate cellulose fiber bundles upon which the strength fundamentally depends (59).

The "hemicelluloses", named first (63) to denote a group of substances in the cell wall considered very closely related to cellulose and as intermediate substances in its development, are being studied intensively. Vincent (86) reports that while most hemicelluloses are soluble in alkali, no alkali extraction ever removes all the hemicellulose from fibrous material; that hemicelluloses are

not homogeneous, some fractions containing uronic acid, and that it is not satisfactory to classify these non-cellulosic materials as "hemicelluloses" and "polyuronides"; that hemicellulose in pulp gives added strength and less resistance to beating; that high hemicellulose content is not indicative of low viscosity; and that it is demonstrated beyond all reasonable doubt that high hemicellulosic content is very desirable in wood pulps. Some (2) have isolated and analyzed "hemicellulose" fractions from aspen holocellulose. The results indicate the presence of galacturonic acid residues, which makes it highly probably that the fraction contains pectic material. Others (48) have found that hemicelluloses from liquefied tissues consist of uronic acid (generally *d*-glucuronic) united to a series of *d*-xylose units with which *d*-glucose may be associated. They resemble gums and mucilages in that on hydrolysis they yield sugar units and a more resistant portion, an "aldobionic acid", which contains the uronic acid.

pH motility curves for "depectinized" cotton continue to shift as treatment with 1% NaOH continues, and from the shape of the curve they never reach a base line (72). The curve does not change in shape after 16 hours. This indicates that some pectic material is retained, although previous work indicated that all was removed after this length of treatment.

The electrochemical activity of collodion membranes depends entirely upon the presence of impurities of an acidic (anionic) nature contained in the collodion used for their preparation (71). Active acidic impurities are largely due to partial oxidation which occurs in the manufacturing process, and partially due to acidic groups which are present in the native cellulose.

In the field of current research in the molecular interpretation of structure and properties, Seymour reports (68):

"Fibers are all high molecular weight products and are related structurally to plastics and rubber. According to Mark the criterion which determines whether a macromolecule is a rubber, a plastic, or a fiber is based upon its ability to crystallize. If the chain-like molecules fit well into the lattice they will crystallize and be fiber-like. If the forces between the chains are greater than 5,000 calories per unit mol, the product will exhibit the properties of a fiber. If the forces are less than 2,000 calories per mol, the product will be rubbery, and products having values in between will be plastics".

Gordon (33) points out the tendency to study fundamentally the polymerization of single pure monomers, and, in the words of Mark and Raff, "although copolymerization is playing an increasingly important rôle in the preparation and technical production of high polymers, only very little is known about the mechanism of this process."

"Recent Progress in Cellulose Chemistry" (5) states that the most promising advance in studies of the degree of polymerization of molecules is in the use of carefully fractionated samples. Calculations by several different methods all lead to similar values which indicate that the molecules are neither fully stretched nor randomly linked or coiled, but assume an intermediate shape of moderate undulation which becomes increasingly kinked as the degree of polymerization increases. They add that it is important to determine the ratio of amorphous to crystalline or ordered regions in cellulose, since the amorphous regions are more easily accessible to chemical attack, *e.g.,* water uptake, absorption of organic vapors and of dyes.

Fibers from Seaweeds

One of the most significant current events in the field of research dealing with cell walls and synthetic textiles is the successful manufacture of "alginate" fibers. Under the title of "Seaweed Rayon" Speakman (74) reviewed the progress in this field in 1945. Tseng (83) in the same year helped to clarify the confused viewpoints of these new

products in a short article entitled "The Terminology of Seaweed Colloids". In conclusion he remarks:

"In view of our incomplete knowledge of their chemistry it is still too early to propose a critical classification of seaweed colloids. It may be said, however, that there seem to be three groups of phycocolloids. First of all, we have the water-soluble ethereal sulfates as represented by agar, carrageenin, and fucoidin; they are similar to mucilages in some of their properties. Secondly, there are the water-soluble reserve carbohydrates consisting exclusively of glucose units; they are represented by laminarin and occupy a position similar to that of starch in land plants. In the third group we have the alkali soluble polyuronides, represented by algin, which are analogous to pectin".

A tentative systematic arrangement of useful seaweeds and seaweed colloids given in diagrammatic form furnishes information with which both biologists and industrialists may conjure (83). The impressive array of cell wall materials, the ease with which many of them may be separated for identification and determination of physical properties, and their chemical relationships to the wall materials of fibrous cells of higher plants, indicate their value for studies fundamental to the understanding of both native and processed cell wall materials.

Of particular interest is the rôle played by sodium and calcium in the current manufacture of seaweed textiles. Speakman and Chamberlain (73), using principles of current viscose practice, report that rayon of satisfactory appearance, handle and strength may be obtained by extruding a solution of sodium alginate into a coagulating bath of N calcium chloride, 0.02 N hydrochloric acid and 2.5% by volume of olive oil emulsified with an agent such as Lissapol C. In a later paper Chamberlain and coworkers (14) state that calcium alginate yarn seems to be suited as the stock material for all purposes. It can be converted into woven or knitted fabrics which can then be made alkali-resistant in finishing by forming chromium or beryllium alginates.

These reactions of seaweed colloids suggest the value of comparisons with the reactions of the pectic material of higher plants (6) as well as the important functions played by calcium in the membranes of living cells. That such comparisons have given and still are giving pause in theoretical developments is indicated in the following quotation (4):

"The fibrous poly-saccharide from seaweed, alginic acid (poly B-niammuronic acid), gives an excellent X-ray fiber photograph, but contrary to expectation the period along the fiber axis is not the same as that of cellulose (10.3 A), but 8.7 A°, in spite of the fact that the chain molecules are undoubtedly in a fully extended configuration. The unification here consists in explaining this paradox in terms of *one and the same set of postulates*, *viz.*, the ordinary accepted inter-atomic distances and bond angles. In both cases the ring is the Sachse "armchair", but at the two ends of this armchair there are two possible directions of the glucosidic oxygen bond: one holds in cellulose and the other in alginic acid. Either configuration may pass to the other by virtue of intramolecular oscillations, from which it follows that 10.3 is not the prerogative of cellulose and the 8.7 period is not the prerogative of alginic acid. It is now conceivable that derivatives of either may be found, under the right conditions, to have either period. Neither are these two periods characteristic of B residues only, for the alginic acid configuration is apparently assumed also by pectin, which is built from d-galacturonic acid residues".

It is to be expected that, from the industrial development of seaweed textiles, valuable information concerning the many types of cell wall constituents there represented, and their relation to the physical properties of both the native and processed states, will be more clearly understood. It is to be hoped that all of the valuable techniques which have been developed in connection with both the molecular and the colloidal interpretations of cell wall composition will be brought to bear upon the problems to the end that the properties of cell wall com-

ponents throughout the plant kingdom may be more accurately appraised.

Conclusion

The biologists, chemists and industrialists of the past century based their interpretations of the nature of cell walls and synthetic textiles upon chemical analyses, microscopic analyses and the general colloidal behavior of the materials exhibited in their native and processed states. The investigations of the present century have added to these the more or less generally used techniques of X-ray diffraction (3), refinements in viscosimetry (76) and osmometry (87), electrophoresis (46), ultra-centrifugation (57), electron microscopy (58), ultraviolet microscopy (37, 69), microradiography (16), microincineration (80), phase difference microscopy (10) and the production of crystalline galacturonates (42). It is encouraging to note that data obtained by means of these techniques are being used in both the molecular and the colloidal interpretations of the properties of cell walls and synthetic textiles. The intensive research now in progress and careful evaluation of the data obtained may lead, within this century, to the solution of many of the problems in structure and composition which are here outlined and briefly discussed.

Summary

1. The manufacture of synthetic textiles was anticipated by Robert Hooke in a treatise on microscopy published in 1665.

2. Researches of John Mercer, Edward Schweizer, and contemporary workers laid the foundations of present industrial practices during the middle of the nineteenth century.

3. In 1885 Count Hilaire de Chardonnet obtained a British patent covering the first successful commercial process for the preparation of artificial silk.

4. Man-made fibers are currently manufactured from plant cell-wall material under such technical names as "cellulose nitrates", "cellulose acetates", "cellulose xanthates" and "cuprammonium mellulose".

5. The trade names "artificial silk", "rayon" and "synthetic fibers" are applied, upon occasion, to any one of these processed forms. The terminology is confused, and efforts are being made to clarify it.

6. Plant fibers are used almost exclusively for the manufacture of synthetic textiles, although seaweeds are now being processed for similar purposes.

7. In the production of man-made fibers the art has preceded the science, and the structure and composition of both native and processed materials are not clearly understood. Accumulated information has led to the development of the "molecular" and the "colloidal interpretation".

8. The molecular interpretation holds that the cellulose molecule is the functional unit which determines the properties of native cell walls as well as their synthetic derivatives. The colloidal interpretation explains the same properties upon the basis of a heterogeneous chemical system, established through the vital activity of the colloidal protoplasm, and persisting, in varying degrees, throughout the treatments involved in industrial processing.

9. Examples from various parts of the plant kingdom reveal the fact that the properties of plasticity and deformability are achieved in native cell walls through the use of non-cellulosic materials; that membranes rich in cellulose are no longer plastic; and that extraordinary procedures are involved in reversing this state of rigidity in the mature cell wall. Industry relies upon more or less drastic chemical and physical processes; the cells themselves bring

about such a reversal through the use of enzymes.

10. It is to be hoped that all of the valuable techniques which have been developed in connection with both the molecular and colloidal interpretations will be brought to bear upon the problems of current importance to the end that the properties of cell walls and synthetic textiles may be more accurately appraised.

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Utilization Abstracts

The Shelterbelt Project Pronounced a Success. In 1934 the most ambitious utilization of living trees and shrubs ever conceived to diminish the injurious effects of adverse climatic conditions, was instituted in the United States as the Prairie States Forestry Project and thereafter popularly known as the Shelterbelt Project. "Its chief purposes were, through tree planting, to ameliorate drought conditions, protect crops and livestock, reduce dust storms, and provide useful employment for a drought-stricken people" in a strip of the country extending from Canada through North and South Dakota, Nebraska, Kansas and Oklahoma into central Texas.

The idea originated with President Franklin D. Roosevelt in 1932 and its execution was stimulated by the drought and dust storms of 1934. It was planned and carried out by the U. S. Forest Service and Soil Conservation Service, almost exclusively on relief funds, beginning in 1935 and continuing until 1943 when the Works Progress Administration was terminated. On the basis of extensive preliminary studies, the project was pursued from 1935 through 1942 by planting 220 million trees and shrubs in 30,223 belts on 33,000 farms, the belts covering 238,000 acres and totaling 18,600 miles in length. Most of the belts were along property lines and varied in length from one-eighth to one, and in a few instances to two, miles. Within the belts the number of rows of trees and shrubs varied from one to 56. The rows within the belts were from eight to 14 feet apart, and the trees were from six to eight feet apart, the shrubs from two to four feet apart.

In 1944 a survey was made in order to appraise the results of the project. Of the more than 30,000 belts originally planted, 1,079 were examined, or 3.6%, which represented 2.7% of the total mileage and about 3% of the 220,000,000 trees and shrubs. Many features were taken into consideration in this survey and a detailed report rendered on the survival of the 44 kinds of trees and shrubs planted. These notes constitute a résumé of that report, excerpts from the summary of which are:

"In terms of meeting the main purpose for which the belts were established, that of protection against wind, the Project was a success. For the area as a whole, 78.4 percent of the belts were rated as good or better, and only 10.4 percent as unsatisfactory. Tree survival throughout the entire area covered was generally good. Survival of those species which were planted in more than 100 rows (probably also in more than 100 belts) ranged from 39.2 percent for ponderosa pine (267 rows), the poorest, to 85.0 percent for boxelder (159 rows), the best.

"Benefits which have already been derived from the program include landscape improvement, control of wind erosion, snow traps along highways, protection of farmsteads, gardens, orchards, and feed lots, providing a haven for game and song birds, furnishing wild fruit for preserves, providing fence posts and small poles for use on the farm, and bringing new districts into the soil conservation program.

"The Shelterbelt Project has been a success." (*E. N. Munns and J. H. Stoeckeler, Journal of Forestry 41: 237. 1946*).

Chemical Utilization of Wood. The very important problem of profitable utilization of the huge amount of wood annually wasted in the United States is one of the chief concerns of the Forest Products Laboratory, operated by the U. S. Forest Service at Madison, Wisconsin. While the Laboratory's approach to the problem is from the chemical standpoint, it is recognized that "economical harvesting and transporting of wood waste so that it can be delivered cheaply for chemical use seems to be the biggest obstacle confronting the chemical utilization of wood".

Such chemical utilization of wood waste may be divided into six categories, *viz.*, pulping, extraction, hydrolysis, destructive distillation, reactions with various chemicals, and chemical treatment to improve the qualities of wood.

Pulping yields not only paper pulp on a large scale but also tannin from chestnut chips on a smaller scale. Waste liquors from pulping processes are sources of soluble lignin, hemicelluloses and wood extractives, all of considerable potential value. Turpentine and tall oil are now being recovered to a limited extent from the sulphate pulping of southern yellow pine. Tall oil is used in drying-oils and soaps. Sulphite waste liquor finds some use as a dust settler for roads. Lignin is serving as a dispersing agent for cement in the making of concrete, and is being incorporated in the negative-plate paste of electrical storage batteries; it also finds use in the manufacture of vanillin, the active constituent in vanilla extract. Soda-mill lignin may become useful for laminated plastics without addition of auxiliary resin, and it has been shown to be useful as a phenolic-resin diluent. The hemicelluloses are converted almost entirely to sugars in the sulphite process, and those sugars, to some extent, are being fermented to ethyl alcohol and used for growing yeast.

Extraction processes still await much development and can be profitably applied at present to only a few species, yielding, in particular, turpentine and rosin from southern pine stumps, and tannin from chestnut and hemlock.

Hydrolysis of the carbohydrate portion of wood to sugar, and then fermentation of the latter to alcohol, represent the generalized process of manufacturing ethyl or grain alcohol from wood waste. "If all the sulphite liquor from pulp mills producing more than 100 tons of pulp a day were fermented, alcohol production from this source would be about 30 million gallons of alcohol per year, which is about 3 percent of the present annual production." Such manufacture must compete with alcohol production from grain and possible production from petroleum.

Fermentation of wood sugars can also produce acetone, butanol, 2,3-butylene glycol and lactic acid, useful as solvents and as raw materials in making synthetic rubber and plastics. And fodder yeast can be grown on the total sugars as well as on the still bottoms.

Destructive distillation of wood, formerly an industry of some size, has dwindled since development of the present method for making synthetic wood alcohol, and revival of the industry is dependent upon the development of new techniques.

Studies in the hydrogenation of wood have shown that lignin dissolved in organic solvents or suspended in water can be made to react with hydrogen gas, producing new cyclic alcohols that show promise as plastic solvents, antiknock agents for motor fuel, and toxic agents.

Lastly, there is the production of modified woods through treatment with resins and in other ways. (*A. J. Stamm, Journal of Forestry 44: 258. 1946*).

Sunflower Seeds. Sunflower seeds contain 32%–45% of edible oil, and the plants have long been extensively grown in the U.S.S.R., Roumania and Argentina for production of oil. More recently the crop has made headway in the U.S.A., Canada, Uruguay, Hungary, Rhodesia and other lands. In 1940, under the impetus provided by the war through a decreased supply of vegetable oils, experiments were undertaken in Great Britain toward raising the plants as a source of oil. The results so far indicate that they can be commercially grown and utilized there. A book of 155 pages and 20 plates has recently been published in London on the subject: Hurt, E. F.—Sunflower for food, fodder and fertility.

Sunflower oil is a semi-drying oil equal to the best olive oil in its medicinal and feeding

value for human consumption. It is excellent for margarine and salad oil and as a substitute for cooking lard. The seeds make good poultry feed and the residue from oil extraction is a valuable livestock feed. (*W. B. Brierley, Nature 157: 604. 1946*).

Medicinal Plants. In northeastern United States—New Jersey, New York and all the New England states—there are 67 wild species of herbaceous plants (listed in the article) possessing medicinal properties that might serve as commercial sources of drugs, but which have not yet been used as such, not even in the recent war emergency. So far as Maine is concerned, for instance, only a little collecting of juniper berries and of lycopodium spores has been profitably conducted by a few individuals.

Cultivation of drug plants in the area, except for temporary spurts, has decreased since World War I. In 1918, for example, four growers in New Jersey raised belladonna on about 35 acres; in 1941 the acreage was practically nil. In some other states, however, including Wisconsin, Pennsylvania, Virginia, Tennessee and Ohio, belladonna was harvested on 400 to 500 acres in the autumn of 1942 as a result of seed distribution by the U. S. Department of Agriculture in the spring of that year.

At least nine other kinds of drug plants (listed in the article) were found in approximately 2,400 nurseries, but of them only *Convallaria* was being raised in considerable quantities. (*R. H. Cheney, Bull. Torrey Bot. Club 73: 60. 1946*).

Pre-harvest Fruit Drop. In 1939 it was announced that premature fruit drop can be prevented in fruit trees by use of hormone sprays, and by 1942 commercial use of such sprays had developed to the extent that 75,000 to 80,000 acres of apples were treated that year in the United States. More recently experiments have been conducted during five seasons on the use of such sprays on five varieties of apple and one of pear at the East Malling Research Station, England. α-naphthaleneacetic acid in concentrations ranging from 2½ to 10 p.p.m. were tried. A large significant gain in crop was obtained with the pear and three of the apple varieties. (*M. C. Vyvyan, Jour. Pom. & Hort. Sci. 22: 11. 1946*).

Peanuts. At the Southern Regional Research Laboratory, New Orleans, a comprehensive investigation is under way concerning the industrial utilization of peanuts. An excellent account of this work was published last year, and these notes are based on that report.

The increased demand for new sources of oil that resulted from the recent war was in part responsible for stimulating the American peanut industry to such a degree that during the war it experienced a five-fold increase in cash value, finally bringing an estimated $200,000,000 annually to Southern farmers who produce the crops, and making peanuts in 1945, for the first time, the number one cash crop in Georgia.

Industrial utilization of peanuts, always secondary in importance to their use as food, involves, primarily, crushing them for oil and use of the residual high-protein meal as livestock feed. For these purposes peanuts are normally used that do not meet food quality standards or that are in excess of food requirements.

In 1940–41 35% of the peanut crop was crushed, producing 171,000,000 pounds of oil and 260,000,000 pounds of meal. Of this production 75% to 90% of the oil was consumed in the manufacture of shortening and oleomargarine; all the meal went into livestock feed.

The industrial problems awaiting solution are concerned in part with finding uses for the by-products of the food- and oil-producing processes, namely, the hulls, skins and embryos, and with obtaining greater extraction of oil—from 5% to 9% of it remains in the meal with present customary methods of hydraulic pressure. About 30,000 tons of hulls and 12 to 15 million pounds each of skins and embryos accumulate annually in the United States as by-products of the major industrial processes. The manufacture of peanut butter is the principal source of skins and embryos. Solvent extraction of the oil is not commercially employed in this country, though that method leaves as little as 1% of oil in the meal.

About 90% of the peanut oil produced in this country goes into edible products, principally vegetable shortening and oleomargarine. Some goes into salad and cooking oils. Other uses of the oil include the manufacture of soap and shaving cream,

face creams and other cosmetics, and pharmaceutical preparations. And still other uses, minor in importance and still more or less in experimental stages, are as a massage oil in the aftertreatment of infantile paralysis; as a carrier of drugs, such as adrenalin and penicillin; in boring compounds, oil sprays and insecticide emulsions; as a textile or other lubricant; for leather impregnation; as a Diesel fuel; and as a gasoline and kerosene substitute. The oil is not suitable, however, in the manufacture of mayonnaise and salad dressings, for it may not remain completely fluid at refrigerator temperatures.

The Southern Research Laboratory is concerned with the development of all these and other possibilities, as well as with the preparation of peanut proteins which may become the basis of textile fibers, adhesives, coatings, sizes and plastics, and a possible source of amino acids. In England peanut protein fiber has been marketed under the name Ardil. (*C. L. Wrenshall, Chemurgic Digest 5(9): 157. 1946*).

Shelterbelts in Russia. In the subtropical districts of Georgia, U.S.S.R., there are miles of tree shelterbelts planted to protect tea and citrus plantations against wind. Some of them are 10 to 12 years old with trees up to 35 feet in height. The best trees for this purpose have been found to be *Sequoia, Cryptomeria,* cypress, tulip, plane and poplar, the most profitable of all, in view of its also furnishing much cordwood, being *Cryptomeria.* In addition to providing shelter the various species also furnish wood and serve as sources of essential oils and resins. (*N. Yushkevich, Journal of Forestry 44: 206. 1946*).

Castor Beans. In 1850 there were 23 castor oil mills in the United States—in Illinois, Missouri, Virginia, Tennessee, Pennsylvania, Alabama and Arkansas. St. Louis was the commercial center of the industry. In 1870 there were only six mills in operation, in Texas, Missouri, New Jersey and Tennessee. In 1880 the domestic production of castor oil amounted to nearly 24 million pounds, and an additional 2½ million pounds were imported. Thereafter domestic production dropped, reaching about 20,000 pounds in 1920, and today there is not any commercial castor bean production in this country. By 1940, however, importations of the beans had increased to 307¾ million pounds, and the mills handling these importations today are on the East coast.

India formerly was the great source of castor beans, but production has shifted to the New World, and during the recent war importations into the United States were almost entirely from Brazil and Mexico.

From the leaves of castor plants the Woburn Chemical Corporation has developed an insecticide, Spra-Kast, and the stems are a source of pulp and cellulose which can be used in making cardboard containers, wallboard, newsprint and kraft and other papers, provided the economics of handling make it profitable. Oil is extracted from the seeds or beans, and the remaining pomace, which contains a poisonous substance that makes it unsuitable as livestock feed, is used as a high-nitrogen fertilizer.

It is the oil, pressed from the seeds, that is the important and commercially valuable product of the plant. It enters into the manufacture of at least 25 kinds of products (listed in the article), and the foremost new development in its utilization is the production of hydrated castor oil, used as a fast drying oil for paint and varnishes. This hydrated oil accounted for 64 million of the 77 million pounds of castor oil used in 1944. Other quantities are converted into sebasic acid and capryl alcohol for the plastics industries.

Establishment of an American castor bean industry and independence of foreign sources involves solution of various harvesting and handling problems, and to this end the services of plant breeders as well as engineers is needed. Breeding work can contribute by providing strains of suitable height with fine stems and capsules that do not drop or shatter too readily; in short, varieties that will be high-yielding, non-shattering, disease-resistant and adapted to mechanized handling. Work along these lines was conducted by the U. S. Department of Agriculture in 22 States in southern parts of the country in 1941, 1942 and 1943, and similar work is being continued at the Bureau of Plant Industry Station, Beltsville, Md., at the University of Nebraska, Louisiana State University and the Illinois Agricultural Experiment Station. (*R. O. Weibel and W. L. Burlison, Chemurgic Digest 5(9): 167. 1946*).

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Utilization Abstracts

By the editor

The Plant Resources of Peru

Cotton, sugarcane, rice, maize, yuca, bananas, flax and olives grow on the coastal lowlands; oca, ullucu, añu, quinua and temperate climate fruit trees in the mountains; cinchona, coffee, mahogany, Spanish cedar, palms, bamboo and cubé in the forested montaña.

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Introduction

PERU's economy, like that of most South American countries, is based upon agriculture. From pre-Incaic days to the present time crop plants have been the most important of her natural resources, and this in spite of the fact that the greater part of her habitable terrain is either inhospitable desert, uncultivable mountain slopes or impenetrable lowland rain-forest. In the face of such difficulties ancient Andean civilizations, culminating in the Incas (1200–1500 A.D.), raised agriculture and agricultural practices to the highest degree encountered in the Western Hemisphere at the time of the Spanish Conquest.

The two most important food plants indigenous to the New World—maize (*Zea Mays* L.) and potato (*Solanum tuberosum* L.)—were possibly brought into cultivation for the first time by ancient Peruvians, who, in their heyday, not only had domesticated about 70 native species but also were familiar with the products of more than 200 different plants. Several of these are familiar species, including:

Chili (*Capsicum frutescens* L. var. *longum* (DC.) Bailey) : The orange-red fruits yield a pungent condiment, cayenne or red pepper, and are used in other culinary ways; also medicinally.

Cinchona (*Cinchona* spp.) : The source of the all-important febrifuge, quinine, and of similar alkaloids.

Cherimoya (*Annona Cherimolia* Mill.) : The green spherical or conical fruits up to 10 inches long are an esteemed tropical dessert fruit.

Coca (*Erythroxylon Coca* Lam.) : The leaves are used as a masticatory by the natives and are the source of cocaine.

Cotton (*Gossypium peruvianum* Cav.) : The seed-borne fibres constitute the world's most important textile material (including other species and varieties of the same genus).

Guava (*Psidium Guajava* L.) : The yellow berry-like fruit, two inches long, is eaten raw or used in jellies, preserves and pastes.

Kidney Bean (*Phaseolus vulgaris* L.) : The common "garden", "snap" or "string bean".

Lúcumo (*Lucuma obovata* H.B.K.) : A name applied to a common edible tropical fruit.

Lima Bean (*Phaseolus lunatus* L.)[2]

Peanut (*Arachis hypogaea* L.)[2]

Pineapple (*Ananas comosus* (L.) Merr. = *A. sativus* Schult. f.)[2]

Tomato (*Lycopersicon esculentum* Mill.)[2]

[1] Formerly Botanist (1943–1945) of the U. S. Government Cinchona Mission, Lima, Peru.

[2] Too well known to need comment here.

Less familiar to us because less widely cultivated outside their native Andes are:

Achira (*Canna edulis* Ker-Gawl.): The tubers are a source of arrowroot.
Añu (*Tropaeolum tuberosum* Ruiz & Pav.): Furnishes an edible tuber.[3]
Arracacha (*Arracacia esculenta* DC.): The tubers are the edible "Peruvian carrot".
Jataco (*Amaranthus caudatus* L.)
Llacou (*Polymnia sonchifolia* Poepp. & Endl.)
Oca (*Oxalis tuberosa* Molina): Furnishes an edible tuber.[3]
Ullucu (*Ullucus tuberosus* Caldas): Furnishes an edible tuber.[3]
Quinua (*Chenopodium Quinoa* Willd.): Furnishes a cereal-like crop.
Ccañihua (*Chenopodium pallidicaule* Aellen): Furnishes a cereal-like crop.

Since the conquest, Peru has continued her gifts of new plants to the world, chiefly to the field of horticulture, including garden favorites in the following genera:

Calceolaria	*Gongora*
Crocopis	*Mirabilis*
Dieffenbachia	*Schinus*
Eustephia	*Stenomesson*
Fittonia	*Tropaeolum*
Fuchsia	*Urçeolina*

Outside this edible and floricultural galaxy is an insecticidal plant, cubé (*Lonchocarpus* spp.). Of little importance prior to this decade, this lowland genus has now become one of the most valuable sources of rotenone. Undoubtedly many other potentially useful species of economic plants remain yet to be discovered.

That many Peruvian plants are now grown widely in temperate as well as tropical parts of the world emphasizes the fact that Peru has a wide range of climates, at least as far as temperature is concerned, brought about not only by her great latitudinal length (3° to 18° south latitude) but also by her high elevation (up to 22,000 ft.). Although situated close to the equator in the north, the cool weather of the Andes makes it possible for Peruvians to cultivate both native and introduced temperate species as well as tropical and sub-tropical species which can be grown of course in the lowlands. Sometimes overlooked, by Peruvians especially, is the fact that certain temperate species, originating in high latitudes, require for their maturing special environmental factors, such as long daylight hours, which cannot be duplicated close to the equator. And certain native plants of the Peruvian Andes may refuse to grow in high temperate latitudes because of similar reasons.

Agriculture in Peru, like the country's natural vegetation, is divisible on the basis of the three principal physiographic zones, known locally as the coast (La Costa), the mountains (La Sierra) and the forested country (La Montaña).[4] Each of these agricultural regions has its characteristic crops, but because of the difficulty and expense of transportation across the Andes, large scale agricultural production is still practiced mainly along the Pacific coast.

Plant Resources of the Coast

Coastal Peru is an almost rainless desert region, yet curiously enough on this narrow belt are grown the country's two most important crops, cotton and sugar. About 52 small rivers flow west-

[3] See abstract of article by Dr. Hodge concerning these tubers, on page 136.

[4] Elsewhere in Latin America the Spanish word "montaña" is used to define mountainous areas, but in Peru it is applied to all forested land whether in the mountains or in the lowlands.

ward to the Pacific from their watersheds high in the Andes. About 40 of these streams have sufficient water to form marginal oases of cultivated land, maintained by irrigation. Some of the smaller rivers dry up completely during a part of the year; others are utilized so

FIG. 1. Map of Peru showing production centers of various crops. Note that tobacco, cotton, kapok, rice, sugarcane, grapes and olives grow in the coastal area; wheat, barley, olives and grapes in the sierra area; tobacco, balata, rubber, coca, cubé, cinchona and coffee in the forested area.

well that their waters are thoroughly exhausted before reaching the sea. Irrigation, which started under pre-Incaic agriculturists, is still the fundamental technical problem of Peruvian coastal agriculture. The best desert areas suitable to crop growing under efficient irrigation are now in use. Any expansion of total crop production on the coast will depend on expensive new irrigation projects. Since 1920, when the Peruvian Government initiated a regular program of desert reclamation, close to 741,000 acres of new land have been turned over to coastal agriculture through national

FIG. 2. Map of Peru showing approximate physiographic divisions of the country, *viz.*, coastal (left) up to 4000 feet, sierra (middle) from 4000 to 22,000 feet, and forested (right) from 200 to 10,000 feet.

financing, and at the present time more than a million acres are under cultivation on the coast. Most of this acreage is in cotton or sugarcane, crops whose cultivation are limited principally to that zone of oases which lies between Ica and Piura. The accessibility of the coastal valleys to the sea and to the main paral-

leling highway has facilitated economical transportation and commerce, and is the major reason why the principal center of Peru's population is on the coast.

Cotton. The main crop plant of the coast and the backbone of Peruvian economy is cotton. It constitutes the principal agricultural export commodity and one of the oldest of the crops, with at least one native species, Peruvian Full Rough (*Gossypium peruvianum*), having been in cultivation since the pre-Columbian period. Cotton has added significance in the country's economy in that the greater part of it is produced on small land holdings. Eighty-five per cent of Peru's total cotton production comes from a high quality, disease-resistant variety called Tangüis, developed in Peru in 1912 from Smooth or Egyptian cotton. Tangüis is the whitest of the world's cotton varieties and always has brought premium prices in the world's cotton markets. The only other important variety today is Pima cotton with a restricted market but bringing a higher price than Tangüis. Of the coastal departments (*i.e.*, the states), Lima produces about 60%, Ica 25%, Piura 15% and the other departments the balance of the total crop. Piura, in northern Peru, is the center of cultivation of the more precocious and faster maturing Pima variety which is thus better fitted to repel insect attacks common in that area. In order to combat the latter, to keep up the fine qualities of the locally cropped varieties and to aid in the development of disease-resistant forms, the Peruvian Government supports the work of cotton specialists at a modern experiment station at La Molina on the outskirts of Lima.

Cotton is treated as a seasonal crop and is planted in the August–September period. During October 800 pounds of guano fertilizer per acre are applied. Harvesting begins in late April, but the pickings are repeated several times from June to August. An acre of land yields upwards of 643 pounds of raw cotton, well above U. S. production, which when ginned equals 240 pounds of clean fiber and 400 pounds of seed. About 5% of the latter is held for re-seeding, while the remainder is processed. In 1942 the number of acres in cotton was 376,766, producing 72,500 metric tons of fiber, of which 11,250 tons were consumed by the 11 local textile mills; 36,571 tons were exported. In the same year Peruvian mills crushed 113,065 tons of cotton seed to yield 19,500 tons of crudé cotton seed oil and by-products.

Sugarcane, introduced shortly after the Conquest, is the second most important money crop in Peru. It is cultivated north of Lima, under very favorable coastal conditions of climate and soils, principally in the irrigated oases of the Chicama, Lambayeque and Santa Catalina valleys (in the Departments of Lambayeque and La Libertad), where 80% of all Peruvian cane is grown. Unlike cotton, a small grower's crop, the greater part of the annual crop of sugarcane is produced by about ten large haciendas. The acreage planted to cane has remained static, and approximately 135,000 acres are currently planted. The yields, which in 1941 in the Chicama and Santa Catalina valleys averaged about seven tons per acre, are very high.

Unlike cotton, sugarcane is a year-round crop which produced 480,000 metric tons of sugar in the period 1941–1942. About 66% of this was exported, principally to Chile, England, the United States and Bolivia. Sugar produced on the coast accounts for about 10% of Peru's exports. Because of high yields, low cost of production and her favorable geographical position in regard to potential markets, Peru's sugar producers are unusually well fitted to endure unfavorable periods in the world's sugar markets. In addition, sugarcane production

has favorable social and economic aspects because the crop can be grown throughout the year, year in and year out, without rotation and on the same land. Employment is thus steady the year round; large sugar estates have grown up, and these offer their workers as favorable a standard of living as exists among any other type of worker in the country.

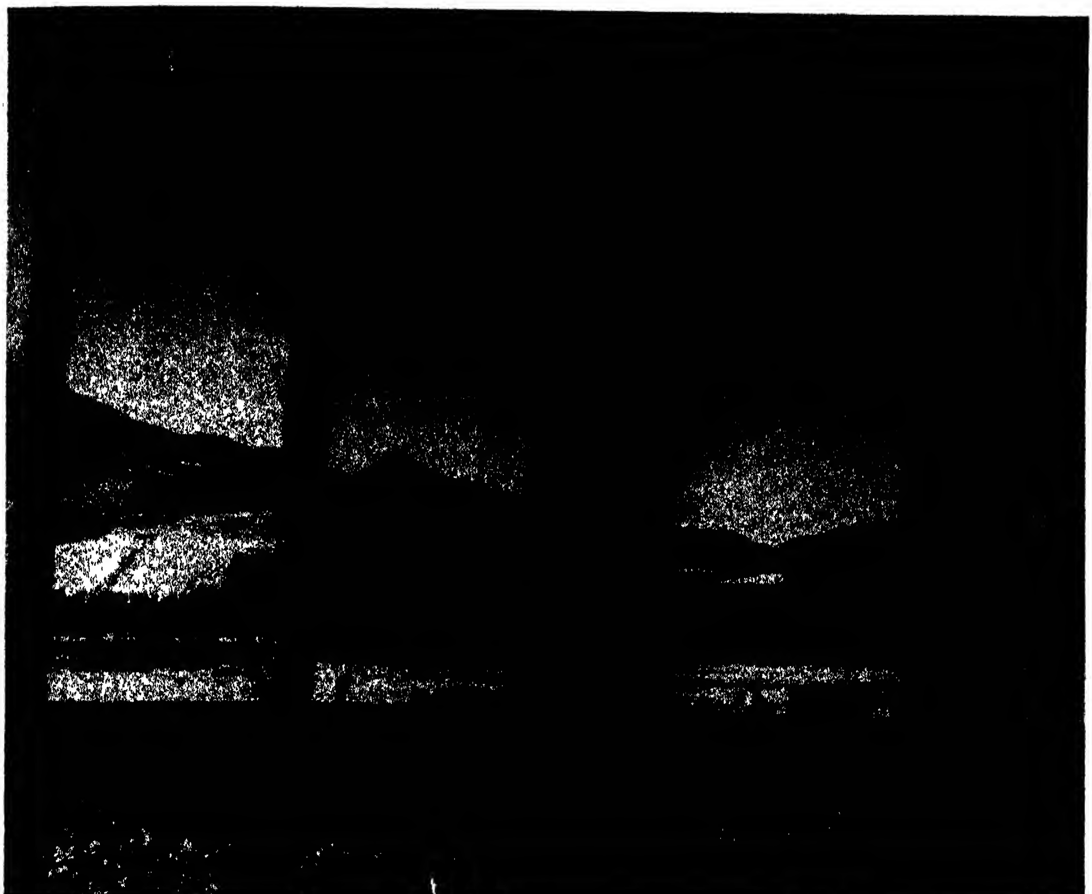


FIG. 3. Ploughing with primitive equipment near Sicuani in the southern Peruvian highlands. These farmers are descendants of the old Incan people. The introduced eucalyptus trees (*Eucalyptus globulus*), bordering the fields, are used for timber and fuel.

The Peruvian sugar industry has not neglected research and experimentation, with the result that sugar production in less than 20 years has been increased 50% without any increase in the total area cultivated. Utilization of the residues from manufacture also goes on. Bagasse is used principally as boiler fuel, although the Grace mill at Paramonga has installed a modern paper factory which makes cardboard containers, wallboard, packing materials and similar products from it which find a ready internal market. Filterpress refuse is used as fertilizer which is run onto the fields *via* the irrigation ditches; molasses, mixed with selected bagasse, goes to make an excellent cattle feed.

Rice, basic food of coastal Peru, is grown in both small and large holdings (totaling approximately 120,000 acres) on the coast, particularly in the sugar-producing departments of Lambayeque, La Libertad and Piura. These departments together produce about 80% of

FIG. 4. (*Upper*). Winnowing wheat in the Vilcanota Valley, south of Cuzco. The white patches on the slopes at the left indicate wheat fields. FIG. 5. (*Lower*). Corn drying in an Indian dooryard in the Sandia Valley of southern Peru.

the annual crop, which in recent years has averaged between 75,000 and 100,000 tons, a total insufficient to supply the internal consumption.

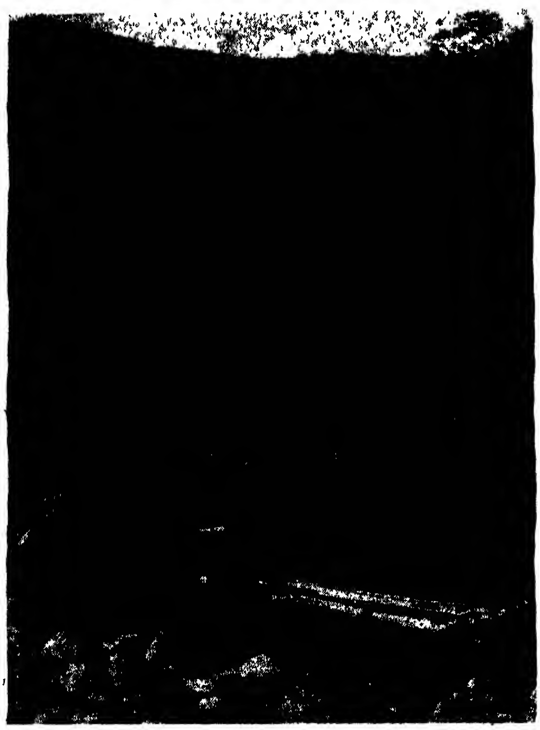
Kapok. Kapok-yielding ceibos (*Bombax* spp.) are common and dominant members of the xerophytic forests, located on the westernmost slopes of the Andes in the northern Department of Piura. Ceibos may be seen in relatively large numbers along both the Sultana-Ayavaca road and the Lambayeque-Huancabamba road. They cover a belt approximately 20 miles wide in the foothills, and grow up to approximately 5,000-foot elevations. In this department the writer roughly estimates that there exist a million acres of ceibos with an average of about ten trees per acre, and with a potential kapok-producing capacity of 10,000 tons per crop year. Peruvian kapok is an uninvestigated potential export product, yet the location of these forests—close to the coastal cities of Sullana and Piura—is especially favorable for solving labor and transportation problems. Cotton-ginning machinery, common in this department, could probably be utilized in harvesting the floss which is usually mature in September.

Other crops. A number of miscellaneous agricultural products also are cultivated in the irrigated valleys of the coast. Flax is planted to a small extent in the valleys of Pativilca and Cañete, but increase in plantings of this relatively new crop must await the solving of serious cultural problems. Olives are important in the Valleys of Moquegua (1000 tons a year), Camaná, Victor, Ilo and Azapa. Castor beans are cultivated in the Department of Piura. The Department of Ica is known for its vineyards which annually produce ten million liters of white and red wines as well as three million liters of piscos, or pure grape spirits. Truck gardens are important in the valleys close to Lima, and all along the coast where irrigation occurs may be found sizable plantings of maize, yuca (*Manihot esculenta* Crantz., the source of farinha and tapioca), bananas and plantains, as well as figs, oranges, mangoes and pineapples.

Plant Resources of the Mountains

The Peruvian sierra, or mountain country, embraces an extensive belt, essentially the Andean mass, including lofty, cold deserts and semi-deserts, grasslands and warmer intermont valleys. The sierra is essentially a high treeless region with a cool climate and a seasonal rainfall, and will support most economic plants requiring such a combination of climatic factors. Planting of a few tuber crops, such as hardy ullucus and certain varieties of potatoes, is possible up to the upper limits of cultivation, about 14,000 ft., beyond which the agriculture of the puna is limited to grazing. The zone of grains lies between 10,000 and 13,000 ft., with maize culture extending up to 11,000 ft., wheat up to 12,000 ft. and barley up to 13,000 ft. Sugarcane is grown at altitudes reaching 8,000 ft., while bananas and oranges occur up to 6,000 ft. Irrigation is utilized with most crops, as on the valley oases of the coast, in order to insure a constant and even supply of water; and because of this use, most sierra agriculture is limited to the larger intermont valleys dissecting the Andean plateau. In the Peruvian highlands rains fall generally from October to April which is the growing season for both irrigated and non-irrigated crops.

Unlike the coastal centers of agriculture which have many large estates, the highlands possess small holdings, owned and worked in many districts by the native Indians of the Aymara and Quechua races which form the great bulk of the sierra population. These peoples are still cultivating their native staple crops of maize, potatoes, ocas, ullucus,



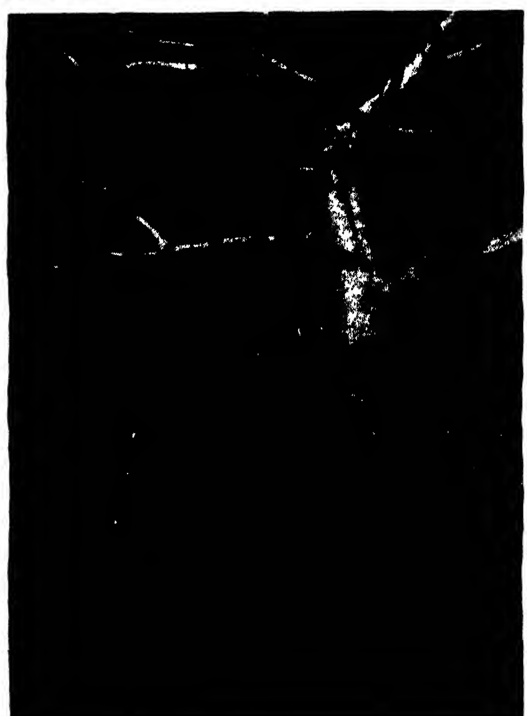


FIG. 6. (*Upper left*). Pruning the old base of a young budded rubber tree at Tingo María, Peru. FIG. 7. (*Upper right*). Seedling rubber trees to be used as budding stock at the joint Peru–U.S.A. Agricultural Experiment Station at Tingo María, Peru. FIG. 8. (*Lower left*). A cinchona bark hunter's camp on the upper Rio Tambopata in the "Ceja de la montaña" of Peru near the Bolivian frontier. High grade quinine bark, *e.g., C. Calisaya,* grows on the ridge at the upper left, and the bark, after removal from the trees, is dried and packed at the camp. FIG. 9. (*Lower right*). Ceibos (*Bombax* sp.) growing in the xerophytic open woodlands of the Chipillico River valley in the Department of Piura. These trees are a source of kapok.

añu, quinua—often on the amazing series of Incan terraces which have persisted to this day in many steep-walled Andean valleys. Although considered the native home of the potato, the highlands of Peru produce a supply barely sufficient to support her coastal and sierra population. Potatoes are, nevertheless, grown throughout the highlands and with the other tuber plants and corn are one of the commonest commodities met with in the primitive Andean markets.

A few varieties of potato and maize have long since been carried around the world, yet it is not generally known that innumerable other obscure varieties with valuable breeding possibilities, still are cultivated only in the high Andes. And it is also surprising that the other flavorsome Andean tubers, in particular the oca and hardy ullucu, have not warranted extensive trial plantings in temperate potato-producing regions of the world. Like the potato with which they are always grown in the Andes they might be developed into new and valuable sources of food.[3] Quinua has had a disappointing introduction to Europe, but even this crop could stand additional study. The importance of quinua as a food among the Indians of the sierra has been recognized by the Peruvian Government which voted a subsidy in 1937 to increase the production and use of this native cereal.

The group of indigenous food plants has been augmented since the Conquest by the introduction of the important Old World grains, wheat and barley, and the forage crop, alfalfa. Wheat formerly was planted on the coast, but today 90% of the country's production is grown—generally without irrigation—on elevated slopes or valleys of the Andes in regions where the more fertile irrigated areas are reserved for corn or potato cultivation. Due to its isolated area of culture, the crop is difficult to transport to the coast, where demand for it is greatest. The present annual wheat production (101,771 tons in 1940) barely accounts for a third of the current Peruvian consumption. The Departments of Junín and Huancavelica are the big wheat producers, while the Huancayo basin is the principal wheat center, accounting for about 40% of the crop. Barley is cultivated to a less extent than wheat and chiefly on the higher and colder altiplano surrounding Lake Titicaca in the southern Peruvian Department of Puno, where it has become an important crop among the highland Indians.

In the intermontane and upper montaña river valleys of the Marañon, Mantaro, Apurimac, Urubamba, Paucartambo and their principal tributaries there is a mild climate suitable to the production of sugarcane. Because of transport difficulties and smaller yield, cane producers of the sierra are unable to compete with coast producers in the production of sugar, and so convert practically all their cane into alcohol, aguardiente, or other industrial spirits. It is estimated that 3% of the sugarcane grown in Peru is crushed in the sierra, but the same region produces 25% of the total alcohol manufactured.

Most of these valley areas also produce temperate and sub-tropical fruits including apples, peaches, plums, quinces, pears, oranges, tangerines, sweet lemons and lemons; wild chirimoyas are also common. Grown to some extent are minor crops such as aniseseed (*Pimpinella Anisum* L.) and pyrethrum (*Chrysanthemum* sp.).

Certain native species of semi-xerophytic middle elevations have been neglected and might be developed into important crop plants suited especially for planting on terrain otherwise unfitted for any other type of agriculture. Examples are tara (*Caesalpinea tinctoria* Domb.) and agave (*Fourcroya* sp.), two plants which are especially abundant in

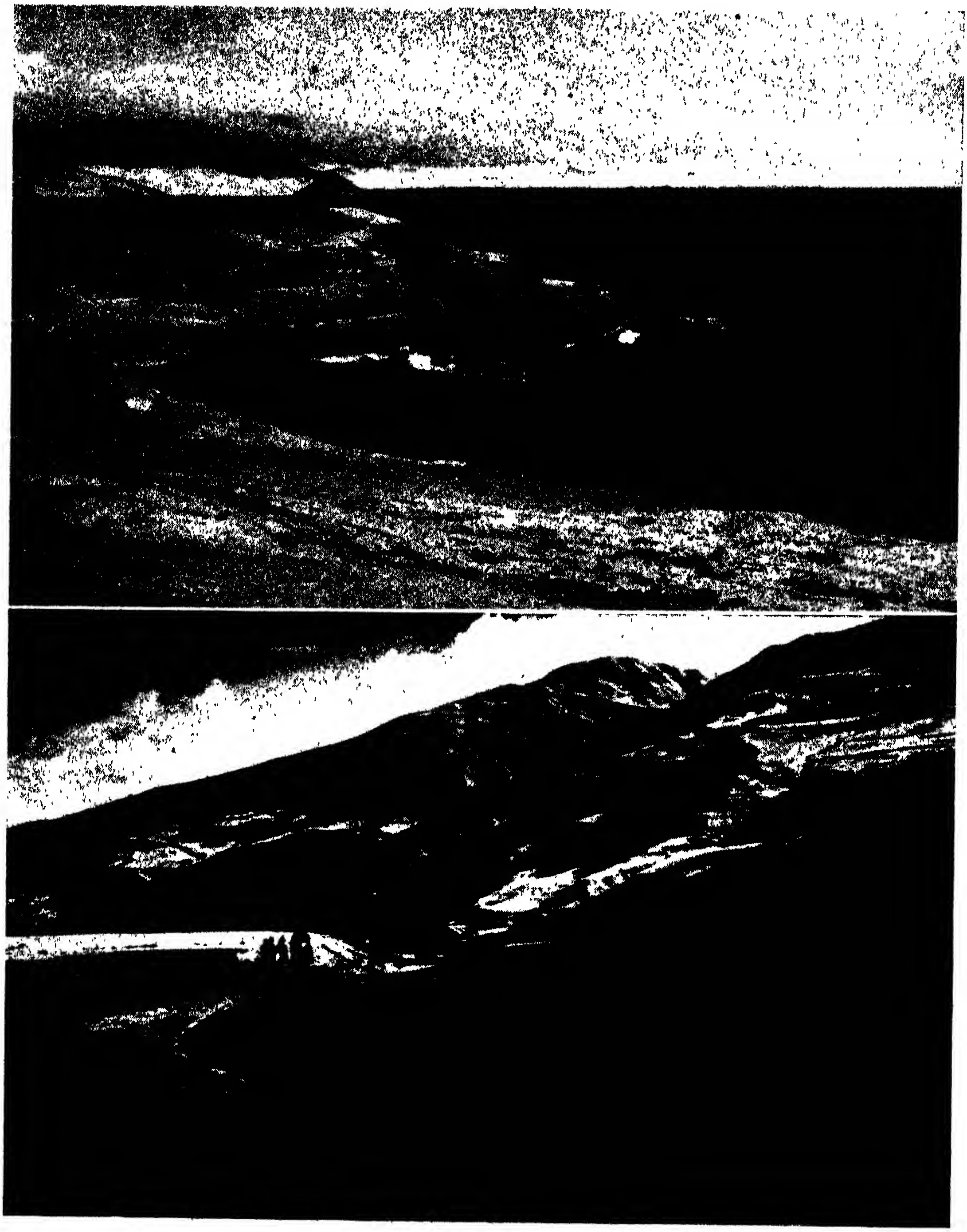


FIG. 10. (*Upper*). Irrigated cotton fields in the typical coastal oasis of Lurín, just out of Lima. This oasis was under cultivation by the ancient Peruvians who had a center, nearby Pachacamac, from which locality this view was taken. The trees are mostly *Salix Humboldtiana*. FIG. 11. (*Lower*). Agricultural use of land in the Vilcanota River Valley, south of Cuzco. On the slopes are wheat fields; on the valley floor, fields of quinua (*Chenopodium Quinoa*) and of an edible lupine (*Lupinus mutabilis*).

the northern half of the Peruvian highlands. The pods of tara, a wild leguminous shrub of the western and intermontane Andean valleys, are very rich in tannin. Moreover, the seeds contain large quantities of pectin which should find some use. Exports of the pod, either whole or powdered, have increased in recent years. In 1943 these exports amounted to nearly 2,200 tons with a value of 490,000 soles ($78,400). Unlike many other tannin plants (*e.g.*, species supplying wood and bark tannins), which are destroyed for their tannin content, tara is uninjured and produces successive crops of pods annually. There is a need for the study of tara culture. Agaves also might lend themselves to cropping in the Andes and could become a more efficient and greater source of fiber which is in universal demand throughout Peru for making baling twine, rope, etc. On the high treeless puna of southern Peru another native plant is of local importance as a combustible. This is the curious cushion-forming yareta (*Azorella yareta* Hauman) whose resinous stems and foliage, when dried, make an intense heat-producing fuel, which is even used to some extent by railroads in the region of the Chilean frontier.

Timber. Perhaps the most serious deficiency of the high sierra country, and the coast as well, is the lack of readily available timber supplies. Most of the habitable highlands lie above the tree-line. The few trees that exist in sheltered areas, like quinuar (*Polylepis* spp.), have been largely eliminated by the highlanders in their unceasing search for firewood. Moreover, the tortuous narrow roads make transportation of lumber by truck up from the nearby montaña forests most difficult. A partial solution to this timber scarcity was the successful introduction of fast-growing Australian species of *Eucalyptus* which are now valuable crop trees throughout most of the highland valleys. The satisfactory growth of eucalyptus at high elevations suggests that other trees, perhaps superior as timber-producers, might also be introduced for forestation purposes.

Plant Resources of the Forested Country (Montaña)[5]

More than 51% of Peruvian territory is forest land, called "montaña", and lies east of the principal Andean axis. The forested area is very moist and is covered for the most part by an evergreen rain-forest formation which extends west from the tropical lowlands of the Amazon basin to the eastern slopes of the Andean front ranges up to timberline at temperate elevations of about 10,000 to 11,000 ft. In northern Peru where the Andes are lower, bits of temperate montaña forest have crept across the mountains and are to be found as irregular patches on the western slopes in the Departments of Piura, Lambayeque and Cajamarca. These scattered patch forests are actually southern outliers of the forest formation of the western Andean slopes of Ecuador.

Peru's forested areas can be divided into two zones, the ceja de la montaña (literally "eyebrow of the forest"), which includes those fringes of low-statured, temperate, montaña forests bordering upon the cold sierra; and the lowland montaña, composed chiefly of tall tropical rain-forests.

In the mountains, at elevations between 2,000 and 6,000 ft., is the center of cultivation for the three C's of ceja crops—cascarilla, coca and coffee. The first two are native medicinal species; cascarilla (*Cinchona* spp.) is represented by trees whose bark constitutes the source of the important alkaloids quinine, cinchonine, cinchonidine and quini-

[5] For aid in preparing this account of the lowland forest species the writer is indebted to Dr. Russell J. Seibert of the Office of Rubber Plant Investigations, Washington, D. C.

dine; and the shrub, coca, whose leaves are much chewed with lime as a narcotic by the Indians of the sierra, is the source of the alkaloids cocaine and tropacocaine.

Cinchona. The genus *Cinchona* is widespread throughout Peru, but the great majority of the forms are of no commercial importance except as possible budding or breeding stock. Most recently exploited because of critical demand in World War II has been the cinchonine-rich bark of *Cinchona micrantha* Ruiz. & Pav., known in northern and central Peru as "huanuco" and in southern Peru as "monopol". The bark of this species averages between 3% and 4% in total crystallizable alkaloids, mostly cinchonine; and more than 1,144 tons of the bark of this species was harvested during the period 1943–1945. Quinine-yielding species are *C. Humboldtiana* Wedd. (averaging 5%–7% of this alkaloid) of the Department of Cajamarca, *C. rufinervis* Wedd. (averaging 4%–5% quinine) and *C. Calisaya* Wedd. (averaging 4%–7% quinine) of the upper Tambopata and Inambari river valleys in the Department of Puno. These species, though relatively rich in crystallizable quinine alkaloid, are small trees which have been intensively sought and so are relatively few in numbers, and hence unimportant. *C. Calisaya* is the parent species of the high-yielding plantation forms (Ledgeriana strains) cultivated so intensively in Indonesia. *C. Humboldtiana,* a little known species of northern Peru, appears to be even richer than wild calisaya and ought to be introduced into any important cinchona-breeding program. Of more importance to Peru is the current attempt to establish local cinchona plantations with the idea of supplying sufficient quinine-yielding bark for her internal demands. A government plantation, Fundo Sinchono, has already been established east of Tingo María in the Cordillera Azul, and has been stocked with high-yielding Ledgeriana strains. This project was initiated with the financial aid of the United States Government, and as partial repayment for Peru's willing help in exploiting her low-grade, wild, cinchona stands during the war.

Coca. Coca is cultivated as a sierra Indian crop on small chacras (farms) situated in the more-accessible, warm, forested valleys lying on the margins of the montaña in the Departments of Puno, Cuzco, Ayacucho and Huánuco. Most cocales, as coca plantations are called, are to be found between 2,000 and 5,000 ft. elevation; the annual production of coca leaves averages between 5,000 and 6,000 tons, but the greater portion of this total is consumed as a masticatory by the highland Indian population. The 200 to 300 tons of leaves which have been exported annually in recent years have been utilized chiefly in the U.S.A. for flavoring soft drinks. Most pharmaceutical cocaine is obtained from higher-yielding leaves produced in Java.

Coffee. Coffee is cultivated throughout the ceja belt, but in appreciable quantities only in the Chanchamayo Valley of central Peru, and in the north, east of Chiclayo, on the Pacific slopes at Monteseco in the Department of Cajamarca. Peruvian coffee is of a rich grade, and the insignificant production is almost wholly exported. Another Old World beverage plant, tea, has been successfully introduced into the upper forest region of the montaña in recent years. Small areas have been planted in the Huallaga Valley near Tingo María, and already locally-grown tea has made its appearance in the Lima market.

The lowland montaña (Peruvian Amazonia) is the country's chief agricultural frontier and is still a virgin untouched area whose limitations are still its inaccessibility and inadequate population. Great tracts of this country probably will support nothing more valuable than forest. Forest products will be, in fact,

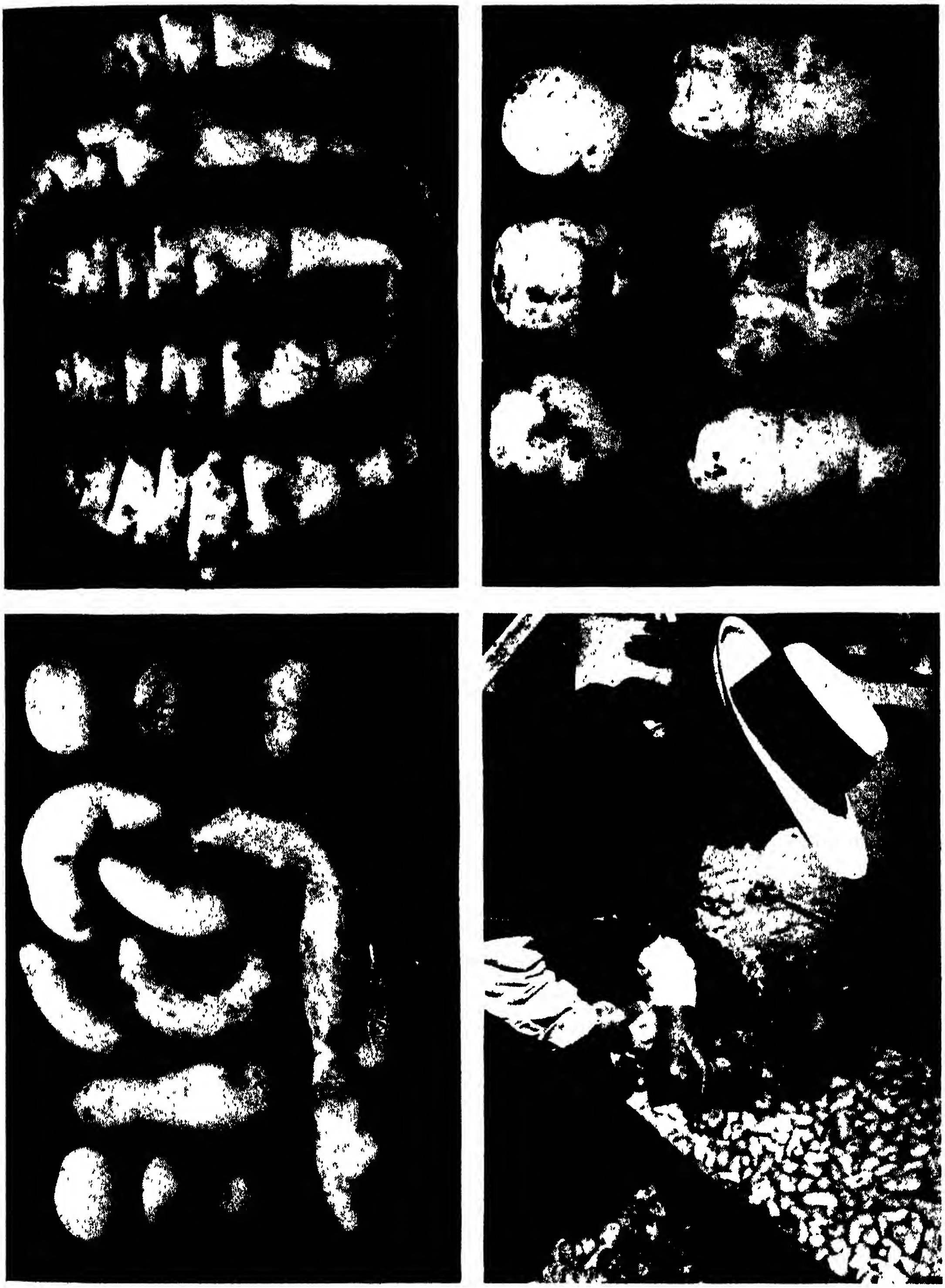


FIG. 12. (*Upper left*). Añu, *Tropaeolum tuberosum*. FIG. 13. (*Upper right*). Oca, *Oxalis tuberosa*. FIG. 14. (*Lower left*). Ullucu, *Ullucus tuberosus*. FIG. 15. (*Lower right*). Potato, *Solanum tuberosum*. The large dark ones are fresh; the small light-colored ones are dehydrated and known as "chuño"; once prepared they keep for years. The broad brimmed, black-banded hat marks the woman as being from Huancayo.

among the first to be exploited, yet the forests are, except for small areas along the rivers or near long-established settlements, largely unknown. Most of the trees, if identifiable taxonomically, are certainly unknown as far as timber possibilities are concerned. A forest survey is a prime necessity for most all frontier regions in the Peruvian montaña.

Timber. A few better-known tropical hardwoods such as mahogany and cedar are being cut for export; and, as resources of fine cabinet wood diminish in other areas of the hemisphere, the expansion of Peruvian lumbering will certainly follow. Lumber mills exist near Iquitos in the Department of Loreto. Small mills have also been located near the eastern termini of the roads running from Lima to Tingo María, to the Chanchamayo Valley, and to Satipo—all in central Peru. Lumber cut in these areas is brought over the Andes by truck for consumption in Lima. Mahogany (*Swietenia macrophylla* King), locally called "aguano" or "caoba", is the most important export lumber tree in Peru today, and this country is the biggest South American producer of this timber. Mahogany is apparently widespread in the Amazonian area, at elevations of 400 to 3,400 feet, and all the way from northeastern Peru to the southern Madre de Dios region where it is very abundant, though unexploited. Unfortunately the greater proportion of Peruvian mahogany, because of its scattered distribution, is inaccessible; and only trees in the central area of the montaña, in the basin of the Huallaga and Ucayali Rivers, are now cut—the logs being then rafted to the mills at Iquitos. To obviate the difficult and expensive search for widely scattered isolated trees—a distribution characteristic of most tropical rainforest species—the Iquitos mills, believing the greatest future for mahogany in Peru to lie in plantation-grown timber, are resorting to experimental plantations of this species. To date, about 15,000 trees have been planted. If such plantations are successful—and no plantation of a tropical American timber tree has yet succeeded—some sort of permanent managed program may be established. Practically the entire mahogany production of Peru is exported as sawed lumber, and the greater proportion in recent years has gone to the United States; 2,500,000 board feet were exported in 1939, and during World War II the Peruvian lumber was a high-priority product, particularly because it excels the same type of mahogany in other areas in its bending, compression and shearing strength.

Second in importance as a commercial timber species is Spanish cedar (*Cedrela odorata* L.), commonly called "cedro colorado". Cedar is an abundant tree along the banks of rivers and streams, and its geographical distribution and exploitation in Peru coincides with that of mahogany, with which it associates. Thus, although cedar is a large and very abundant tree in the Department of Madre de Dios, its exploitation likewise is limited to the Huallaga and Ucayali valleys. As with mahogany, the timber is floated to Iquitos. The fine wood of cedar is the most widely used construction timber in eastern Peru, and besides is the only native timber shipped in large quantities to western coastal Peru *via* the long Amazon River and sea route. Small quantities of cedar are exported.

It is interesting to note that these two most important commercial hardwoods are species widespread in tropical America. Their exploitation in Peru dates from a comparatively recent time and post-dates their use elsewhere. Not a single tree species of Amazonia is of similar economic importance, yet this is certainly not due to the fact that such native species are absent from lowland Peru but rather can be explained by the fact that the other valuable timbers have yet not only to be discovered but also

need to have their wood properties investigated scientifically. Important fine hardwood species aiding the expansion of the Peruvian lumber industry will undoubtedly be encountered among the Peruvian representatives of the Lauraceae as well as among such locally important timber species as tornillo (*Cedrelinga catenaeformis* Ducke) of the Upper Huallaga; and castaña (*Bertholletia excelsa* H.B.K.), estoraque (*Myroxylon Balsamum* (L.) Harms), huacapu (*Lindackeria maynensis* Poepp. & Endl.), mashonaste (*Anonocarpus amazonicus* Ducke), palo vibora (*Phyllanthus* sp.), quillobordon (*Aspidosperma subincanum* Mart.), and tahuari (*Tabebuia* sp.)—all of the Peruvian Madre de Dios. At least one of these timber species, castaña, is the producer of a potentially-important export item, the Brazil nut, which is also utilized locally to make oil. The species is very abundant—two or three trees per hectare—in the Peruvian Madre de Dios.

Latex. Timber is but one class of products obtained from tree species of lowland Peru. One of the better-known non-timber products is the latex of the Para rubber tree (*Hevea brasiliensis* Muell.), called "jebe fino" and widespread throughout the great Amazon basin. The saga of rubber's introduction to the Far East is too well known to be repeated here. Suffice it to say that World War II stimulated the return and development of a plantation rubber industry in Latin America. Peru's production of wild rubber in recent years has been insignificant, and even with the stimulus of the recent war the greatest annual production was slightly less than 1,000 tons. Yet present domestic requirements are only about 500 tons per year, a quantity which could be produced regularly, especially if the new plantations initiated in the northeastern part of the country are successful. Iquitos and Puerto Maldonaldo are the chief collecting centers for wild rubber. Peru has aided the Hemisphere Plantation Program especially in supplying wild seed from disease-resistant and extremely high-producing strains, not hitherto known to exist in Amazonia. Many of these wild types are from the out-of-the-way Madre de Dios section where they were discovered by the botanists of the U. S. Department of Agriculture. Careful selection and breeding of these new strains at the several experimental rubber plantation centers of Latin America should produce stock which can be grown even in Peru with its ravaging South-American leaf blight. Disease-resistant rubber can be then a new permanent and readily-available "cash crop" for the small farmer of the eastern lowlands.

Goma debil (*Hevea lutea* Muell.) and caucho (*Castilla Ulei* Warb.) are two other widely distributed latex trees producing poor-grade rubbers. Next to the Para rubber tree, the most important Peruvian latex-yielding species is *Manilkara bidentata* A. DC., scattered wild trees of which supply on an average annually several hundred tons of balata, a non-elastic substance used in the manufacture of insulation. The principal balata-producing areas of the montaña are the basins of the Putumayo, Marañon, Napo, Ucayali, Nanay and Huallaga Rivers. The coagulated latex, gathered from felled trees, is shipped to Iquitos for export. Miscellaneous other latices—obtained principally from *Parahancornia amapa* Ducke and species of *Sapium*, *Pseudolmedia* and *Lucuma*—, are sometimes used as balata adulterants.

Palms. Potentially one of the most important groups of plants of the Peruvian montaña, and one of which very little is known, is that of the palms with a widespread distribution throughout Amazonia. Only a single species, *Phytelephas macrocarpa* Ruiz. & Pav., the tagua palm, is of much economic importance, its hard white seed supplying the

"vegetable ivory" of commerce, which recently has been exported from Iquitos in amounts averaging about 1,000 tons annually. Although only the tagua palm finds more than local use there yet exist dozens of potentially more important palms whose products are at present used only by lowland forest Indians. The chambira palm (*Astrocaryum* spp.), besides producing one of the strongest epidermal leaf fibers—locally made into cord for fish lines, hammocks, *etc.*—also has seed kernels rich in palm oil. The fine pulp oil of various species of the genus *Jessenia* also has commercial possibilities; and chonta or pijuayo (*Guilielma gasipaes*) has a tough, close-grained, flexible wood which could be utilized in the manufacture of high-grade sporting articles such as fish-poles, gun-stocks, *etc.* A distinguished authority on palms has recently remarked that the United States has been importing palm oils from halfway around the globe, even though a larger concentration of oil-yielding palms exist in Latin America, with a center in Amazonia, than anywhere else. Peru has her share of these potential but little-known oil producers and should take advantage of their presence, for not only are most palms easily grown in plantations but also many of them—unlike the other species of the tropical rain-forest—form extensive and natural pure stands which lend themselves admirably to exploitation.

Bamboo. The bamboos are another forgotten group which some day may find commercial importance in the lowlands. Marona (*Guadua* sp.) of the Madre de Dios region is a common bamboo whose large culms are very durable and apparently resistant to termites. Foreign bamboos may also prove valuable, and the group needs study from the standpoint of a possible source of wood pulp, a sorely needed item throughout Latin America.

Cubé. The most important recent gift of the Peruvian montaña to the world is the leguminous shrub cubé or barbasco (*Lonchocarpus Nicou* DC.) whose rotenone-bearing roots, long-used by Indians as the source of a fish poison, have been found also to have very effective insecticidal properties. Up to the last decade most commercial cubé root was collected by Indians from their semi-wild forest plantings, but during recent years many small and very successful commercial plantations have been started in the lowlands, particularly in the Iquitos and upper Huallaga regions. These cubé plantings, totalling approximately 7,000 acres and yielding at present about 1,400 tons of crude or powdered roots annually, are not only the primary source of the world's supply but are also the most important export from Peruvian Amazonia. The recent "discovery" and rise of cubé from a mere fish poison of forest Indians to one of the foremost natural insecticides makes one wonder how many other plants, known and used in various ways by lowland Indians, might have economic possibilities in the world's economy. Ethnobotanical studies in Peru are certainly as important as any forest survey and may prove once and for all whether such Indian drug plants as, for example, ayahuasca (*Banisteria* spp.), chuchuhuasha (*Heisteria pallida* Engl.) and oje (*Ficus glabrata* H.B.K.), have any actual value in medicine. Undoubtedly many an important aboriginal plant is still unknown to the world at large.

Other forest crops. Other crops are locally important in various parts of the montaña, but in most cases agricultural practices are primitive, consisting of temporary cultivations where the forest has been felled. Logs and stumps are usually left in place in such clearings so erosion is limited. After a few years of chacra farming the plot is abandoned for a new one. The most important field crops on these small lowland clearings

are maize, beans, rice, sweet potatoes, yuca, and plantains. . . . the two last-named being the staple foods of the region. In the few localities where transportation difficulties are lessened, agriculture is more advanced. This is especially true of such valleys as the Chanchamayo which has trans-Andean highway connections with Lima, and which, as Lima's "fruit basket", supplies the capitol with oranges, bananas, avocadoes, papayas, etc. Small plantations of sugarcane are widely dispersed in the montaña; cacao is produced in the Departments of Loreto, Amazonas and Cuzco; tobacco, a state monopoly, is grown in Tumbes, San Martín and Loreto.

Development of Resources

For years the network of lowland rivers has served as the only means of transportation into the montaña. Products originating in the area and destined for coastal Peru have had to be placed aboard ocean freighters at Iquitos. From that river port they have had to move down the Amazon, through the Panama Canal and then south to Peruvian ports. Transportation costs have thus made prohibitive the development of agricultural resources in the montaña on any large scale.

Peru is taking the initial steps to develop the montaña. Her difficulty hinges not only on deficient transportation but also on the lack of population in her eastern departments. Her problem is shown by the fact that the montaña comprises considerably more than 50% of Peru's total area, yet the population density in the same region is scarcely one person per square mile. For this reason, and rightly, Peru is pushing projects for colonization along several of those trans-Andean roads which have already penetrated into the lowlands. Among these are the highways into the valleys of the Marcapata, the Satipo, the Chanchamayo, and into the upper Huallaga and Ucayali valleys near Tingo María and Pucalpa. In these valleys colonization centers and agricultural stations have been set up and are working hand-in-hand in order to guide new settlers in all phases of tropical agriculture. One of the most important of these Peruvian stations, located at Tingo María, has been established in coöperation with the Department of Agriculture of the United States Government, which has supplied resident specialists in the various fields of agriculture. The most important projects under investigation at present deal with rubber, tea, cinchona, cubé and tropical food plants. Peruvian personnel for this and other agricultural experiment stations, located not only in the montaña but also throughout the whole country, are trained at La Molina, the Government Agricultural School in Lima.

As yet no forest or soil conservation has been initiated in Peru. In a country whose timber resources are vast and unknown this is a serious deficiency. One of the first important tasks should be a forest survey, but forest legislation and organization should also be promoted.

Another need of Peruvian agriculture is greater diversification of crops to enable the country to be self-supporting, at least as regards food plants. With more than sufficient acreage for growing essential crops, Peru yet has to import such basic commodities as rice and wheat, and potato shortages are often frequent in various sections of the country. With better cultural practices and the introduction of modern farm equipment, particularly in the sierra, Peru could make long strides in this direction. The sierra Indians especially, whose ties have long been with the soil, should be schooled in modern agricultural practices. They constitute the sierra population; and unless they are educated, any agricultural program in the important highland region will be a failure.

A forward step in Peruvian agriculture was taken in 1943 with the formation of the Inter-American Coöperative Food Production Service, known as SCIPA, made up of a group of Peruvian and North American agricultural specialists. Prominent on the agenda of this organization are such projects as the increase and improvement of the production of food products; development of plans for crop adjustment; development of new acreage with agricultural colonization; soil conservation; further development of extension work; provision of loans and other means of assistance to small farmers and growers; studies and dissemination of information regarding benefits of diets; and plans for the improvement of transportation, storage and distribution of agricultural products.

Utilization Abstracts

Edible Andean Tubers. In the Andean highland valleys of Venezuela, Colombia, Ecuador, Peru and Bolivia, at elevations of 9,000 to 14,000 feet, there are four important cultivated edible tuber plants. One of them, the potato (*Solanum tuberosum*), is widely known and world-wide in cultivation. The other three have not been accorded the same publicity as has the potato, nor have they been subjected to the same breeding care, and they are therefore only of local importance to the natives in the regions where they are grown. For many centuries they have served as native sources of food, but their cultivation today is being gradually abandoned.

One of these tubers is oca or occa, known around Bogota as "híbia" and in part of the Venezuelan highland as "cuiba". It is the underground portion of *Oxalis tuberosa,* and in some areas is nearly as important as the potato, being the principal crop grown on the terraces of precipitous mountainsides. The upright, branching, succulent herbs, two to three feet tall, do not appear to set seed, as is true of many plants long in cultivation, and propagation is accomplished by cutting up and planting the two-to-three-inch tubers. Several named varieties, distinguished by the color of the tubers and by their degree of sweetness, are recognized by the Peruvian Indians. Oca is planted in primitive fashion at the beginning of the rainy season, and similarly primitive harvesting occurs in April and May. Since the starchy tubers, especially in the bitter varieties, contain crystals of calcium oxalate, they must be mellowed before being eaten, and this is accomplished by placing them in the sunshine for several days. They are then prepared for eating, raw or cooked, in a variety of ways. For storage purposes the tubers are converted into a desiccated form known as "chuño", as is also done with the other tuber crops. This conversion involves prolonged submergence in dammed flowing brooks and subsequent drying and freezing.

Next to ocas in importance are the tubers of *Ullucus tuberosus*, known locally in various regions of its cultivation as "melloco", "ulluco", "olluco", "lisas", "papaslisas", "chuguas", "rójas", "ruba" and "timbos". They resemble small potatoes and exist in several color variations. The plant itself is potato-like in general habit.

The third tuber closely resembles that of *Oxalis tuberosa* and is variously known as "añu", "mashuar", "apina-mama", "isaña" and "cubio". It is the product of *Tropaeolum tuberosum,* a twining plant resembling in foilage its better known horticultural relative. This tuber is less important to the natives than the other two, and medicinal qualities are attributed to it in their folklore. (*W. H. Hodge, Jour. N. Y. Bot. Garden 47: 214. 1946*).

Cedar Oil. In Texas there are three factories extracting cedar oil from mountain cedar [*Juniperus mexicana*] for use in perfumes, leather dressings, furniture polish and similar products. (*Anon., Texas Chemurgic News, as reported in Chemurgic Digest 5(10): 192. 1946*).

The Versatile Soybean

China's most valuable gift to the Western World—the food of millions for centuries and an ingredient in modern adhesives, plastics, foaming solutions, spreaders, waxes, soaps, linoleum, paints and numerous other industrial products.

W. J. MORSE[1]

THE soybean, the "Little Honorable Plant" of the Orient and so much in our news during the war years as the "Wonder Bean" and the "Miracle Bean", and even the theme of poems, has become one of the most valuable, if not the most valuable, of China's gifts to the people of the Western World. With its almost unbelievable number and variety of uses, it may be called the most remarkable of all plants. With an ever-expanding and amazing versatility, it has risen from an emergency crop to one of major importance, in fact, a highly essential and vital crop in our international war emergency program. It has won its way to its present recognition as a valuable aid to good farming; a commercial worthwhile crop; a useful, nutritious human food; a valuable protein feed for all kinds of livestock; and a source of raw material for numerous essential industrial products.

Nomenclature

The soybean is an annual summer legume native of southeastern Asia, and is also called the "soya bean", "soja bean" and "Manchurian bean". Botanically, the soybean usually has been referred to the genus *Glycine* and has been called *Glycine Soja* (L.) Sieb. Zucc., as well as *Glycine hispida* (Moench) Maxim. The late Dr. C. V. Piper, in an extensive botanical study, came to the conclusion that it must be named *Soja max* (L.) Piper. Other botanists, still considering the soybean to be a member of the genus *Glycine*, call it *Glycine max* (L.) Merrill. The cultivated soybean, on the basis of genetic data, is thought by many investigators to have been derived from *Glycine ussuriensis* Regal and Maack which grows wild throughout much of eastern Asia. This species is prostrate in habit of growth; has long, fine, twining stems; small, narrow leaves; appressed hairs; purple flowers; small, compressed pods; and small, oblong seeds of a sooty black color. The change from the wild to the cultivated species is thought to have occurred through qualitative and quantitative changes due to gene mutation, unaccompanied by any change in number of chromosomes. A plant with characters between the wild species and the cultivated forms has been described by a Russian botanist as *G. gracilis* Skvortzov.

History

The early history of the soybean, like that of most important food plants, is lost in obscurity. Ancient Chinese literature, however, reveals that it was extensively cultivated and highly valued as a food centuries before written records were kept. Story tellers of the Far East have related for generations, with untold variations, story-book tales of the remarkable history of the soybean. One

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of the oft-told legends and perhaps the oldest, for it undoubtedly refers to the wild soybean now found growing in the waste places of oriental countries, tells of the first use of the soybean for food. A rich caravan laden with gold and gems pulled out of an eastern Chinese village one evening, bound for a distant settlement. On the second day out in a region of mountains and waste land, the caravan was besieged by bandits. Merchants and servants took refuge in a rocky cave. When food supplies were exhausted and starvation faced the caravan, a servant ate beans from a vinelike plant. His vitality soon returned, and immediately the hopeless men began gathering and pounding the beans into a flour upon which they survived until help arrived. From then on, so the legend goes, the miracle soybean became the staff of life in China.

The soybean is said to be one of the grains planted by Hou Tsi, a god of agriculture. The first record of the plant is contained in a materia medica describing the plants of China, written by Emperor Sheng Nung, the "Heavenly Farmer", in 2838 B.C. The crop is repeatedly mentioned in later records, and it was considered the most important cultivated legume and one of the five sacred grains—rice, soybeans, wheat, barley, millet—essential to the existence of Chinese civilization. Seed of the soybean was sown yearly with great ceremony by the Emperors of China, and poets extolled its virtues. The records of ancient Chinese literature, with innumerable references on methods of culture, varieties for different purposes and numerous uses for food and medicine, indicate that the soybean is perhaps one of the oldest crops grown by man.

Engelbert Kaempfer, a German botanist who spent three years, 1690–1692, in Japan, was the first to make the soybean known to Europeans. Although Kaempfer discussed in detail the various food products prepared from the bean by the Japanese, the soybean aroused but little interest. In France the Jardin des Plantes, Paris, received in 1739 packets of soybean seed from Chinese missionaries. The Royal Botanic Gardens, Kew, England, grew soybeans as early as 1790. The plants were treated merely as botanical curiosities until the experiments by Professor Friedrich Haberlandt of Vienna in 1875 and subsequent years. Haberlandt published in 1876 the results of his investigations in much detail. Although Haberlandt strongly urged use of the soybean as a food plant for man and animals and interest was increased in its cultivation during the experiments, the soybean failed to obtain any great importance in Europe until about 1909. At that time immense quantities of beans were imported from Manchuria by several countries for the production of oil and oil meal. Through the efforts of the oil manufacturers, soybean flour found favor in the manufacture of various foodstuffs. During World Wars I and II the soybean and its products, oil and oil meal, became highly essential in the manufacture of numerous vital food and industrial products. This was especially true of Germany in World War II when soy flour was used extensively by the army in field camps. Although attempts to grow soybeans in European countries have extended over many years, in general the climatic conditions are not well suited to successful culture of the crop. At present, production is confined largely to parts of European U.S.S.R., Austria, Bulgaria, Jugoslavia, Czechoslovakia and Rumania, the largest production being in Rumania.

The first mention of soybean in American literature is by Mease in 1804 who wrote: "The soybean bears the climate of Pennsylvania very well. The bean therefore ought to be cultivated". In 1829 Thomas Nuttall grew a variety in the botanic garden at Cambridge, Mass.,

FIG. 1 (*Upper*). Wild soybean (*G. ussuriensis*) in the foreground, *G. gracilis* to the right, and the cultivated form in the background. FIG. 2 (*Lower*). A field of Patoka soybeans grown in Indiana for commercial purposes.

and from his observations wrote: "Its principal recommendation at present is only as a luxury, affording the well-known sauce, soy, which at this time is only prepared in China and Japan". The Perry expedition to Japan in 1854 brought back two varieties of soybeans which were distributed by the Commissioner of Patents. Frequent references to the plant occurred thereafter in agricultural literature under such names as "Japan pea", "Japan bean", and "Japanese fodder plant". Later, many introductions were made by several experiment stations and missionaries, but it was not until 1898 that a systematic introduction was made by the U. S. Department of Agriculture from Asiatic countries. Increase of acreage and production in the United States has been closely correlated with the introduction of varieties from the Orient and their improvement through selection and hybridization.

Present Day Production

In the Orient the soybean is grown more intensively in Manchuria than in any other country, occupying about 25% of the total cultivated area. It is a dominating factor in the economic life of the country, for as a cash crop it provides fully half of the farm income and more than half of the total volume of the freight handled by the railroads. It is estimated that from one- to two-thirds of the production of beans is exported to Japan, China and European countries, 15 to 20% being utilized for food, feed and planting, and the remaining seed employed for oil extraction.

In China the soybean ranks fifth in cultivated crops, occupying nearly 13,000,000 acres or about 9% of the total cultivated area. China consumes practically all of her production, about 220,000,000 bushels—50% for food, 27% for oil extraction and other purposes, 10% for stock feed, and 8% for planting. The quantity of beans used for oil and industrial purposes is relatively small, and exports are quite negligible. Japan and Korea are large producers, Japan consuming all of her own production and importing large quantities from Manchuria and Korea. South of China the soybean is cultivated more or less in the Philippines, Siam, Cochin China, India and the Netherland Indies.

In the Americas acreage and production are concentrated largely in the North Central States of the United States, although the crop is grown fairly extensively in the Southern States. In 1946 the twelve North Central States, with 89% (9,606,000 acres) of the total acreage produced 92% of the record seed crop of 196,725,000 bushels—Illinois, Iowa, Indiana, Ohio and Missouri being the five leading states. The phenomenal increase in acreage and production in the United States may be attributed to the following factors: improved adapted varieties; mechanization of the crop through improved machinery for seeding, cultivating and harvesting; being one of the more profitable cash grain crops; less damage from diseases and insect pests than in other common crops; being a dependable producer of forage or grain, even under adverse weather conditions; being a legume fitting favorably into corn belt rotations and crop-control programs; and available industrial markets.

The development of superior varieties for various purposes adapted to a wide range of soil and climatic conditions has been one of the most important factors in increased acreage, production and utilization of the soybean. In the breeding of varieties, as with other crops, the main objective has been increased yield. During the past few years, however, with increased utilization of the crop for food and industrial purposes, plant breeders have been called upon to give special attention to oil and protein, nu-

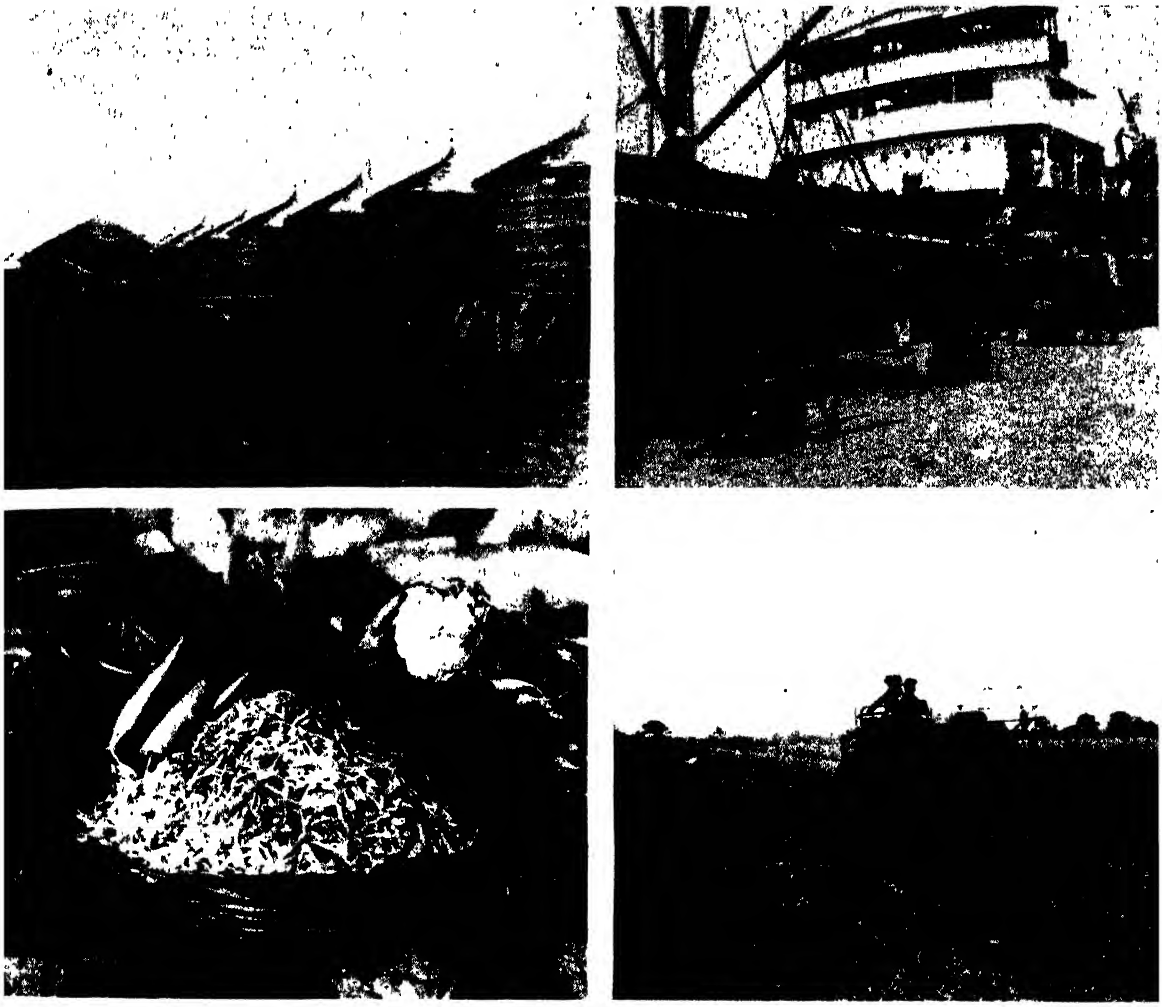

FIG. 3 (*Upper left*). Soybeans stored in osier bins in a Chinese merchant's storage yard, Kaiyuan, Manchuria. The soybean is a dominating factor in the economic life of Manchuria. FIG. 4 (*Upper right*). Loading bags of soybeans into a freighter at the Dairen, Manchuria, wharves for shipment to European oil mills. It is estimated that from one- to two-thirds of Manchuria's soybeans are exported to China, Japan and European countries. FIG. 5 (*Lower left*). Sprouted soybeans in a small product stall in Peiping, China. Soy sprouts afford a fresh winter vegetable rich in vitamins. FIG. 6 (*Lower right*). Combining soybeans in the Mississippi Delta. Mechanization, through improved machinery, of seeding, cultivating and harvesting the crop has been one of the principal factors in the phenomenal increase in acreage and production of soybeans in the United States.

tritive value, and quality of beans. With the development of improved varieties the importance of adaptation to different conditions has become realized by breeders. The average yield per acre in the United States has increased from 11 bushels in 1924 to 20.5 in 1946. The old standard varieties having an oil content of 15 to 18% have been almost entirely replaced by varieties having from 19 to 22%. Moreover, through introduction and selection, vegetable varieties much superior in flavor and cooking quality to the varieties used for oil have been developed. At present, about 100 varieties are available commercially, of which 72 are forage and grain types and about 28 vegetable types.

Diseases

As with most other crops in the first years of production in a new country, the soybean has been relatively free from serious epidemics of disease, except for occurrences of pod and stem blight in the Mississippi Valley and sclerotial blight in the Southern States. The record increases of soybean acreage during the past two or three years have, however, greatly emphasized the disease problems of the crop, especially in the large producing areas. Fields have been observed in which a large percentage of the plants has been killed by disease. Since a number of the pathogens causing soybean diseases are known to be seed-borne, increasingly severe losses must be expected if the seed sources are permitted to become more and more highly infested. Pathologists and agronomists have recognized the urgency of this disease problem and in disease surveys have found that certain diseases are increasing in prevalence and are a distinct menace to production in many localities of our large soybean region. Effective control measures for the major soybean diseases are being studied by pathologists of many agricultural experiment stations and the U. S. Department of Agriculture. It has also been found that there is more or less resistance to diseases in some varieties, thus furnishing a basis for the development of highly resistant or immune varieties by the plant breeders.

FIG. 7. An improved variety of soybean with high seed-yield and high oil-content, developed for commercial purposes.

Use as Food

In oriental countries the soybean is grown primarily for the seed which is used largely in the preparation of numerous fresh, fermented and dried food products. For thousands of years the protein part of the diet of hundreds of millions of oriental peoples has been supplied or supplemented largely from soybean products. Fermented, the soybean yields all their different sauces which furnish the basic flavoring for their food; pressed, it gives oil for cooking; sprouted, it gives a fresh vegetable rich in vitamins; picked when green, it makes an excellent green vegetable; ground dry, it makes flour; soaked, ground and with water added, it provides milk, and the curdled milk furnishes the famous bean curd or tofu—the boneless meat of the Orient—used in the form of various cheeses and as a meat substitute; roasted beans are used as salted beans and in cakes and candies; roasted beans and bean flour enter into numerous health drinks; fermented bean pastes are used in soups and for preserving vegetables; and boiled beans are eaten with millet, rice or kaoliang. The soybean has thus meant bread, meat, milk, cheese and

vegetables to these people and has furnished what appears to be a well-balanced diet at a relatively low cost.

Although the many and peculiar uses of the soybean for food have long been appreciated by the peoples of Asiatic countries, it is only within comparatively recent years that it has received serious attention as such in either Europe or America. The soybean, in view of its richness in digestible nutrients as indicated partly by its unusually high percentages of protein and oil, deserves high rank as a food. European scientists for many years have realized the high nutritional value of soybean protein and fat, and Europe was one of the principal importers of soybeans from Manchuria and the United States. In 1938 one European country published an army field cook book containing nearly 300 recipes in which full fat soy flour was used to supplement meat, milk, eggs and cheese in the soldier's diet.

The importance of the soybean as an economical and valuable source of food in the human diet has become more generally recognized by the average citizen in the United States. In past years most people have looked upon the soybean as a stock feed, a crop to enrich the soil, or for processing for oil and oil meal. Extensive nutritional investigations by domestic science schools and commercial laboratories have shown that the soybean ranks higher in food value in both the green vegetable and mature stages than other beans and peas. Proteins, fats, minerals and vitamins are the most costly constituents of our diet. The high content and unique character of the protein and fat of the soybean explain in part its high nutritional value. In both the green and dry forms, it contains more fat than other legumes, but its carbohydrates are lower. It can be relied on as a good source of nutritionally important mineral elements, containing more calcium, iron and phosphorus than any of the cereals and two to three times as much calcium as other beans and peas. The calcium and iron contents of both green and dry soybeans compare favorably with any list of foods that are generally considered rich sources of these elements.

Soybean foods receiving most attention at the present time in the United States are soy flour, soy grits, soy flakes and soy meats, of which flour is the most widely used. Improvement in processing during the past few years has resulted in the elimination of the raw bean flavor so characteristic of the first soy flours placed on the American market. There are three general types of soy flour—full fat (high fat), medium fat and low fat. Full fat flour contains about 20% of oil and 40% protein; medium fat, 5 to 7% oil and 45 to 48% protein; and low fat, approximately 1% of oil and 50 to 53% protein. Primarily a protein concentrate, soy flour's principal function is to add nutritive value to other foods. Soy flour, soy grits and soy flakes are used with wheat flour in bakery goods, macaroni and other paste goods, soups, candies, ice cream powders, prepared baking mixes, breakfast foods and confections, and as an extender in various meat products. Soy flakes have been used to some extent in the brewing of beer. Soy meats are split or coarsely ground soybeans, dehulled and debittered, and are used in place of roasted nuts in confections. Other food products now on the market are baked beans, canned and quick-frozen green vegetable beans, salted roasted beans, breakfast foods, soy butter, candies, chocolate, curd or cheese, diabetic foods, flavorings, health foods, cones, meat-like products, milk substitute (liquid and powder), soy sauce, soups, sandwich spreads and infant foods.

Vegetable varieties of soybeans, now available in all sections of the soybean-growing region, have become quite popu-

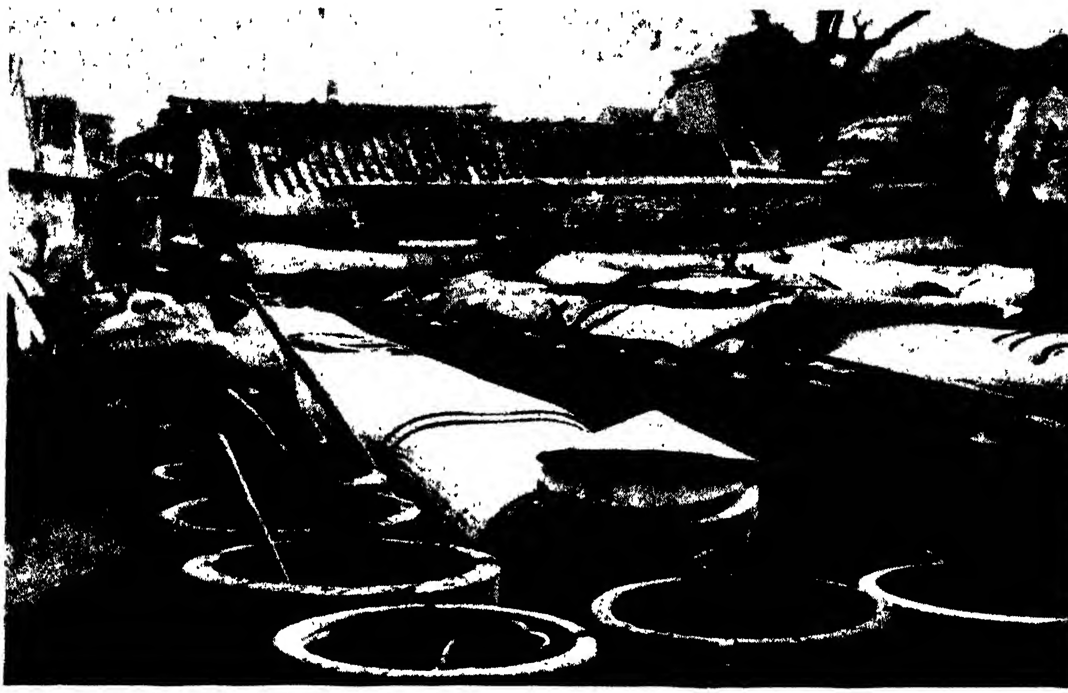

Fig. 8 (*Upper*). Brewing soya sauce in the yard of a soya sauce factory, Peiping, China. Fermented, the soybean yields a variety of sauces which furnish the basic flavoring agent for oriental foods. Fig. 9 (*Lower*). Soybean curd, the boneless meat of the Orient, used as a meat substitute and in the form of various fermented cheeses.

lar as green-shelled beans used in the same manner as green peas or lima beans. These varieties are much superior in flavor and cooking quality to the varieties used for processing for oil and oil meal. Many of them are handled by growers and seedsmen and are being used extensively for green vegetable beans in home gardens and by canning and quick-freezing companies. The soybean has been used in the United States primarily as a forage crop, being preserved as hay or silage or cut and fed as soilage. It is also pastured with hogs and sheep quite extensively in some sections and is used as a green manure or cover crop, especially in the sugar cane areas of Louisiana.

Use as a Source of Oil

In addition to its forage and food values, the soybean contains a valuable oil. About 1920 the production of soybeans greatly exceeded the requirements for planting, and several oil mills in the Midwestern States became interested in the possibilities of the soybean as an oil seed; by 1929 oil mills were a potent factor in the production of the crop for commercial purposes. The soybean now appears firmly established in the industrial world, and the oil produced has come to fill an important place in the domestic vegetable oil supply and economy. In the early part of 1944 nearly 100 oil mills, specializing in soybean processing, were operating in the United States. These mills, located at 80 points in 18 states, had a crushing capacity of about 130 million bushels per year. In addition, more than 100 other oilseed mills, mostly cottonseed mills, were crushing temporarily or only part of the time. Late in 1944 there were 137 soybean-processing mills, counting those under construction and those definitely planned with priorities approved. The total annual capacity of these mills was estimated at 172 million bushels. The scale of processing operations expanded rather slowly at first, but as larger supplies became available, processing greatly increased. In the period 1924–1925 only 307,000 bushels of soybeans were crushed, but in 1943–1944 142,258,000 bushels of a total production of 193,125,000 bushels were processed.

The three methods in general use for obtaining oil from soybeans are hydraulic pressing, expeller or screw pressing, and solvent extraction. Expellers or screw presses handled 74% of the soybeans processed in 1940–1941, and solvent extraction about 23%. There has been a rapid expansion in processing capacity for both expeller and solvent types of plants since the middle of the 1930's. The rate of expansion of solvent processing has been the greater of the two.

The yield from a bushel (60 pounds), on the average, processed by an expeller press is about 9 pounds of oil and 48 pounds of meal. The meal contains from 40 to 45% protein and 4.0 to 5.5% oil. The average yield from a bushel of soybeans processed by the solvent method is about 10.5 pounds of oil and 45 pounds of meal. Solvent process meal contains 43 to 48% protein and 1% or less oil. Variations from these averages may occur to a considerable extent in individual cases because of differences in oil and protein content of different varieties and of the same varieties grown in different localities, and because of the differences in efficiency of operation of individual plants.

Soybean oil has qualities that make it adaptable to a wide variety of uses. It is classed as a semi-drying oil, and its fatty-acid composition is another quality which gives it versatility. During the past 30 years the principal use made of soybean oil has been at times in soap, at other times in the drying industries, and most recently in food products. Much progress has been made during the

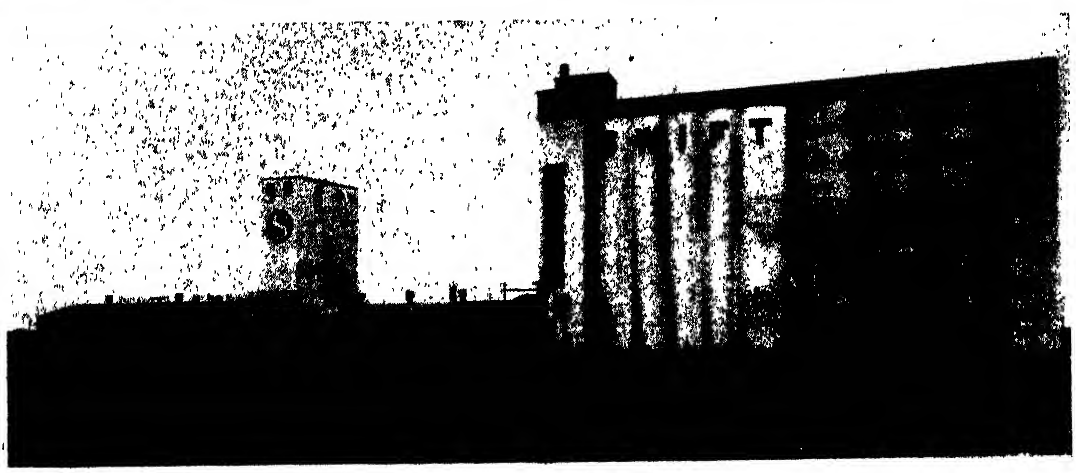

FIG. 10 (*Upper*). Vegetable soybeans, now available in all sections of the soybean-growing region in the United States, have become quite popular as green shelled beans. They are extensively grown as such and are used by canning and quick-freezing companies. FIG. 11 (*Lower*). In 1944 there were 137 soybean-processing mills in the United States, the combined annual capacity of which was estimated at 172 million bushels. More than 142 million bushels of the total production of 193,125,000 bushels were processed during 1943-1944.

last decade in methods of refining, bleaching and otherwise improving the oil for food uses. In 1939 soybean oil comprised 5.6% of the total production of fats and oils, including butter, lard, tallow and all vegetable oils, for domestic materials in the United States, and in 1943 the proportion accounted for by soybean oil was 11.4%. More than 50 different food products containing soy-

bean oil are manufactured in this country; the principal food use at present is for shortening. In 1943 soybean oil made up 42% of the total oils and fats used in shortening, 40% in margarine and 16% in other edible products. Other products using the oil include soaps, cleaning compounds, disinfectants, lecithin, insecticides, foundry oils, paints, enamels, lacquers, varnishes, linoleum, oilcloth, printing ink, oil clothing, resins, grease and lubricating compounds, rubber substitutes, patent and artificial leather, waterproof goods, candles, medicinal oil, sticker for lead compositions, textiles and sulphonated oils.

Soybean Meal

Soybean oil meal remaining after processing the beans for oil is a most valuable product and has wide usefulness. Production of soybean oil meal in the 1920's (1924–1925, about 8,000 tons) was small, but production increased rapidly the following years. In 1938–1939 it was 140 times as great as in 1924–1925, and in 1943–1944 (nearly 3½ million tons) was more than three times that in 1938–1939. Soybean oil meal, a highly concentrated and nutritional feed and food, is and has been extensively used for all kinds of livestock in American and European countries. It has been gaining favor among livestock feeders for several years. It is estimated that from 90 to 98% of the total domestic disappearance has been for this use. Less than 1% of the production of soybean meal was used in making soy flour in the years immediately preceding World War II. Soy flour manufacture greatly increased during the war, the quantity produced in 1943 being equivalent to about 3% of the total soybean crop. Foreign governments purchased large quantities of soy flour and other soy proteins to fortify bread and various products. Industrial products, in which the oil meal or protein is used, include adhesives for plywood, molding compounds, core binder compounds, plastics (especially in the automobile and electrical appliance industries), paper coatings, paper sizing, cold-water paints, foaming solutions, pollen supplement for bees, textile fiber (vegetable wool), spreaders for insect sprays, finishing waxes and waterproofing for textiles. Substantial tonnages of soybean meal were used in the manufacture of mixed fertilizers before the war, but this was not permitted during the war. In oriental countries the oil meal is used very extensively for fertilizing purposes—rice and various truck crops—and also to some extent as livestock feed.

A comparative newcomer in our midst, the soybean has found a vitally important and almost indispensable place in our agricultural and industrial economy. From the status of a little-known oriental plant it has become a crop of high economic importance, and at the time of our greatest need, due to the exigencies of war, it has proved its unique usefulness as a source of highly nutritious food and feed and of an almost limitless variety of industrial products.

Utilization Abstracts

Tree Bark. The great Weyerhauser Timber Company of Longview, Wash., has announced "that commercial processing of the bark of Douglas fir and other trees is about to begin in a factory now being built there. The bark will be made into several materials of different usages, among them being a plastic, a glue, and a component for insecticides". (*Chemurgic Digest 5(13): 222. 1946*).

The Production of Minor Essential Oils in the United States

The oils of dill, lemon-grass, tansy, wormseed and wormwood are distilled from cultivated plants; those of cedarleaf, cedarwood, erigeron, pennyroyal, sassafras, sweet birch, wintergreen and witch-hazel from wild plants; and together they all constitute a minor industry for which production figures are not readily available.

A. F. SIEVERS[1]

Introduction

THE production of essential oils in the United States is a relatively broad subject which may be discussed from several standpoints. There are the oils that are produced from imported materials by those who specialize in the production and marketing of essential oils for the consuming industries. This phase of essential oil production has no interest for persons concerned with the utilization of native domestic plants for this purpose or the cultivation of aromatic plants as sources of such products. The present paper deals entirely with the production of oils from plant material of domestic origin. A discussion of the subject on this restricted basis requires a further rough division of the oils into two groups, namely, those produced on a relatively large scale, and those that are of relatively minor inportance from the standpoint of their economic value and the bearing their production has on the nation's economy. In the first group are turpentine, the production of which is a part of the naval stores industry of the southeast; mint oils, produced in the North Central and Pacific Coast States; and citrus oils, produced as by-products of citrus fruits in the citrus-growing regions of the South and West. Adequate information concerning the production of these oils is quite generally available. In the second group of oils are several distilled from cultivated crops and others obtained from wild plants. The oils included in this group are in no case produced in large amounts, and their production offers very limited opportunities to additional farmers and landowners, since most of them have very limited and specific uses.

As the title suggests, this paper deals with the production of these minor oils. Five of them are obtained from cultivated plants, namely, wormwood, wormseed, tansy, dill and lemongrass. The remainder, cedarleaf, cedarwood, sassafras, erigeron, pennyroyal, wintergreen, sweet birch and witch-hazel, are distilled from wild plants. Information on the production of these oils from both cultivated and wild plants is very meager. Agricultural census reports sometimes include statistics on acreage and production of some of the cultivated species, but for the years between the publication of these reports production figures can be obtained only by local investigations and inquiries. Oil production figures are altogether lacking for the wild species. The year to year production is

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probably known quite accurately by the trade, but there are no published statistics.

Oils Distilled from Cultivated Plants

With the exception of lemongrass and dill, the oils obtained from cultivated plants have been produced for many years, usually in restricted areas. Wormseed is produced only in central Maryland where this crop has been grown for more than a hundred years. Wormwood has long been a minor crop on a few mint farms in Michigan, Indiana and Oregon. Dill oil is a comparative newcomer, since the substitution of dill herb oil for the herb itself in the flavoring of pickles is of fairly recent origin. The most recent introduction in this group is lemongrass oil which is now the product of a single producer in Florida.

Wormwood. This oil is obtained by distillation of the perennial herb *Artemisia Absinthium* L. Its production in recent years has been confined to southwestern Michigan where about 500 acres of the crop are grown on black muck soil in St. Joseph and Cass counties, and western Oregon where 27 acres were grown in 1939, according to the U. S. Census 1940. The crop is grown mainly by producers of mint oil. The plants are started in seedbeds in spring for fall transplanting to the field or in fall for spring or summer transplanting. The soil in the seed bed must be well prepared and in fine tilth, and the seed scattered evenly on the surface and left uncovered. Most growers prefer to transplant the seedlings when they are five or six inches high, but smaller and much larger plants can be used. The seedlings are loosened with a fork, lifted from the ground, gathered and tied into large handfuls. When the plants are rather large the tops are cut off on a chopping block with a sharp knife or hatchet. The bundles are then dipped in water and placed close together in a

FIG. 1. Wormwood (*Artemisia Absinthium*). (*From Stephenson & Churchill, Medical Botany, 1835.*)

crate in which they are taken to the field. The planting is done with celery or mint transplanting machines. At present-day farm wage scales it costs about $30 to $35 to grow the seedlings for one acre and set them in the field. Cultivation sufficient to control weeds is required, and hand weeding is generally necessary if the field is to remain productive for several years. The more successful growers use fertilizers, usually a fall

FIG. 2. Tansy (*Tanacetum vulgare*). (*From Stephenson & Churchill, Medical Botany, 1835.*)

application of 3–12–12 and about 200 pounds of ammonia nitrate per acre in the spring.

Wormwood is harvested when in the early-to-full bloom stage. A grain binder pulled with a tractor with a power take-off is used. The wormwood stems are coarse and tough, hence the extra power required. The bundles are put in small shocks and allowed to cure for several days after which the oil is distilled in mint-distilling equipment. The yield varies greatly, ranging from seven or eight pounds per acre from poor fields to as high as 40 pounds in exceptional cases. On the average, 20 or 25 pounds may be expected if the crop is well handled and the season is favorable. If the weeds are well controlled a wormwood field remains productive for several years. The crop does not appear subject to serious diseases or insect pests.

Practically all growers of wormwood produce the oil under contract extending over five to ten years. The oil has only one important use, namely, as a therapeutic component of a liniment for man and animal. The manufacturers of this liniment provide the contracts for the growers. Since there is no outlet for the oil for other purposes, production in excess of the quantity contracted for is inadvisable. There is therefore no opportunity for any considerable increase in wormwood acreage in the regions where it is now grown or for its introduction elsewhere in the country.

Tansy. Like wormwood, tansy (*Tanacetum vulgare* L.) is also a very minor crop on some mint farms. Buyers of this oil report that the average annual production is not more than 1,000 pounds. This amount is obtained from about 100 acres in southwestern Michigan and northern Indiana. In 1946 about 60% of the acreage was on a single large mint and truck farm in Michigan.

Tansy is not a very popular crop. The market demand for the oil is limited because it has only a very limited use in medicine, and the price fluctuates greatly, having ranged from as low as $2.00 to $9.00 a pound. One reason the crop is grown at all is that once established it will continue productive for years.

The crop is started by setting the field

with young plants five to six inches high, pulled from established fields and set in rows three feet apart with transplanting machines. The usual cultivation and some weeding is necessary the first season, but the plants spread rapidly and broadcast over the field in a year. Thereafter, due to the dense growth, weeds are largely suppressed. The crop when in bloom usually is harvested with a grain binder. If labor is available the bundles are placed in shocks; otherwise they are left on the ground to cure. One grower cuts his crop and cures it in the swath like mint. It has to cure somewhat longer than mint before being distilled due to the heavier stems.

Wormseed. The volatile oil of American wormseed, *Chenopodium ambrosioides* L. var. *anthelminticum* (L.) Gray, has been produced from this cultivated plant without interruption for more than a hundred years in Carroll and adjoining counties in central Maryland. The reason why this small special industry has never shifted to other regions is not known. The plant is adapted to a rather wide area, and experiments have shown that it can be grown elsewhere. Here again is a product used only for one purpose. It is an efficient vermifuge, due to its principal constituent, ascaridole. For a long time it has been a most important therapeutic agent for the control of certain intestinal parasites. For many years, however, it has to some degree been replaced by carbon tetrachloride. As is always the case with crops yielding products of limited use, overproduction has frequently occurred, especially following years when the price of the oil was attractive. The market value of the oil has fluctuated greatly but not entirely due to supply and demand. In some seasons, for reasons not always understood, the oil has been low in ascaridole content with a corresponding reduction in value.

Although this crop is grown in such

FIG. 3. Mexican tea. (*Chenopodium ambrosioides*). (*From Degener, Flora Hawaiiensis, 1934.*)

a limited area statistics on acreage and production are not always available. According to the Agricultural Census of 1940, the production in 1939 was 38,281 pounds by 240 growers on 927 acres. Later figures are not available. The seed is sown early in spring in outdoor seedbeds much like tobacco seed. When the seedlings are four to five inches tall they

FIG. 4. Dill (*Anethum graveolens*). (*From Esenbeck Plantae Officinales, 1828.*)

are set in the field with tomato planters in rows so spaced that the usual farm cultivation implements can be used. The type of plant grown is shorter and bushier and produces more seed than the wild form. Since the covering of the seed contains a high percentage of oil this type yields more oil per acre. In early fall the crop is harvested with a mower with a buncher attachment, as used for seed clover, and allowed to dry partially before it is distilled. The yield of oil obtained ranges from 10 to 40 pounds per acre.

The quality of wormseed oil depends on its ascaridole content which is easily affected by several factors. If the crop is harvested when too immature the ascaridole content of the oil is low. The temperature of the condenser water and the rate of distillation must be carefully controlled. Under certain conditions ascaridole is quite soluble in water, and some producers redistill the distillate water and thus recover much of this important constituent.

Dill. The dill herb obtained from *Anethum graveolens* L., which is so widely used for flavoring pickles, consists of the leaf, small stems and seed, the latter in various stages of maturity. The successful use of dill oil as a substitute for the herb requires that the oil possess the same flavor as the herb. Since the leaf oil and seed oil are quite different it is essential that the oil be distilled from herb harvested at the stage at which it is used for pickling. To accomplish the harvesting and distillation at exactly this stage is therefore a chief concern of the grower.

Dill oil was first produced in the North Central States about 15 years ago in response to the demands of pickle and kraut manufacturers. Ohio, Indiana and Michigan have been the principal centers of production, but in recent years the production has shifted to Oregon and Idaho. For several years the center of production was in the vicinity of Berne, Indiana, where up to 500 acres of dill were grown and six or seven stills were in operation. At that time the growers received $4 to $5 a pound under contract. A decline in price resulted in a gradual reduction in acreage until at the present time only about 5% of the former acreage is grown there. Information on

the acreage in the Northwest is not available, but at present the principal production of the crop is apparently in the Willamette Valley in Oregon.

In Indiana dill is sown directly in the field with a beet or bean drill early in spring in rows about 22 inches apart. The crop is ready to harvest in 90 to 105 days. It is harvested usually about the middle of July when the earliest seed has ripened, using a grain binder. The herb is allowed to cure in the field for a day or two and then distilled with the same equipment as is used in distilling mint. It requires from 2½ to 3 hours to exhaust the charge. The yield ranges from 15 to 50 pounds per acre. At times a second crop is obtained the same year, but the yield is small and usually unprofitable. There are several varieties of dill, some of which are not suitable for the purpose because they yield less oil or oil of poor quality.

Japanese mint. A variety of mint, *Mentha arvensis* L. var. *piperascens* Malinvaud, which for years was grown almost exclusively in Japan and is hence called "Japanese mint," is the only commercial source of natural menthol in normal times. During the recent war this mint was grown extensively in Brazil, and it remains to be seen which of these countries will become the principal supplier of menthol in the future.

This variety of mint is closely related to the peppermint grown in this country, but it produces an oil with up to 80% of menthol and which is therefore a much better source of this product than the American peppermint oil with only 50% of menthol. The species was grown successfully in California about 20 years ago when the high price of menthol made the crop profitable. During the recent war, when menthol was once more of high value, it was again introduced into that State in the general vicinity of Shafter where it was also grown previously. However, interest in the crop could not be sustained when greatly increased Brazilian production of menthol and the end of the war clearly pointed to an early decline in the price of that product.

The Japanese mint is less hardy than American mint and is therefore not so well adapted to the mint-growing sections of the North Central States. Experimental plantings in many parts of the country have shown that the menthol content of the oil is generally highest when the crop is grown in the northern States and in California. The plant grows vigorously under irrigation in California and produces two cuttings a year. The yields of oil average 60 to 70 pounds per acre and are larger than elsewhere, and since the oil contains about 80% of menthol the crop is undoubtedly best adapted to that State. The higher returns more than offset the higher cost of production.

The crop is grown and distilled like American mint. Extracting of the menthol from the oil is accomplished by refrigeration which causes the menthol to crystallize. The oil is separated from the crystals with a centrifuge and then again refrigerated, and the process thus repeated several times. The dementholized oil is poor in flavor and not generally acceptable for the purposes for which American peppermint oil is used. The Food, Drug and Cosmetic Act requires that goods flavored with Japanese mint oil or the dementholized oil be labeled "flavored with corn mint." It is not practical for the average grower of this mint to undertake extraction of the menthol, and the general practice has been for the growers to sell the oil under contract to the principal consumers of menthol or to dealers in oils who have the facilities for economic separation of the menthol.

Lemongrass. On the reclaimed land of the Everglades in southern Florida there is at present the only acreage in this country of a true tropical essential

nessee, North Carolina and other States from wild plants of *Hedeoma pulegioides* (L.) Pers., but its production gives so little promise of profit that attempts to produce it are frequently soon abandoned. The high cost of collecting large quantities of scattered, wild growing plants is no doubt the principal reason. The operations are so sporadic and the amount of oil produced is so limited that

FIG. 6. Fleabane (*Erigeron canadense*). (*From Bentley & Trimen, Medicinal Plants, 1880.*)

no reliable information or statistics concerning the subject can be obtained.

Erigeron. The prolific weed *Erigeron canadensis* L., common in abandoned corn and other fields in the Middle West where it is known as marestail, is the source of small quantities of erigeron oil distilled by mint farmers from time to time in southern Michigan and northern Indiana. The oil finds a limited use in pharmaceutical preparations. Production is extremely sporadic, and no statistics concerning it are available. The plant is never cultivated, but when it grows very abundantly in a field in the mint or wormwood growing section the "crop" is likely to be bought for a few dollars by somebody who owns a still, and the oil distilled from it. The buyer harvests it with a binder or mower, allows it to dry several days and then distills it. The yields are reported to be from 25 to 30 pounds per acre when the stand is heavy.

Sassafras. The common sassafras *Sassafras albidum* (Nutt.) Nees, widespread and abundant on waste lands in the eastern third of the country, is the source of sassafras oil. This oil is widely used as a flavor in carbonated beverages and dentifrices and for its medicinal properties in some pharmaceutical preparations. It is produced mainly in various sections of Kentucky, Tennessee, North Carolina, Virginia and southern Indiana and Ohio. All parts of the sassafras tree contain the oil in varying quantities, but only the roots and stumps are utilized. Some of the oil is distilled in small, rather primitive stills which are probably moved from one location to another as new supplies of the needed material must be found. There are several larger operators with more modern stills. The raw material for these is obtained either from farmers who secure it on their land and deliver it to the still or through the distiller's collection crews who are provided with the necessary equipment. The trees are felled and the stumps then pulled out of the ground. They are cleaned of adhering dirt and hauled to the distillery where they are run through a hogging machine and reduced to small chips which are stored above the still into which they are loaded as needed. The bark of the root contains from 5 to 9% of oil, whereas the wood contains less than 1%. When the sap is flowing in the spring or when the ground

is frozen, much of the bark will strip from the roots and remain in the ground when the stumps are pulled. It is the practice, therefore, to engage in this operation in late summer or fall. Distillation is conducted in the usual way. Steam is admitted from a boiler and blown through the chips in the still. The operation is completed in about four hours. The yield of oil varies from 1.5 to 2%, according to the proportion of wood and bark in the charge.

Cedarleaf. In northern New York, Vermont and to a less extent in New Hampshire and Maine the production of cedarleaf oil has long been a small local industry carried on by farmers during the time of year when they are not occupied by usual farm work. The oil, used for general scenting purposes, is obtained from the leaves and small branches of the white cedar, *Thuja occidentalis* L., abundant in that region. With few exceptions the distillations are conducted with rather crude equipment, mostly constructed from materials locally available and at small cost. They are of the type where steam is admitted into the still from an outside source and no fire is maintained under the still. Old saw mill or hoisting engines are generally used as a source of steam. The stills are set up near springs or streams which provide ample water for the condenser through gravity flow or by means of pumps.

The most desirable material for distillation consists of the leaves and small branches removed from trees about five feet in height. Such material is reported to yield from 1 to 1.5% of oil. It is cut up into small size and packed tightly in the stills. These are in most cases made of spruce planking, tongued and grooved. The seams are calked with clay or other suitable material. Some producers use steel tanks. The stills are operated by admitting steam into the tub directly from a boiler.

The equipment is moved from time to time, sometimes to several locations within a season. This is necessary to avoid hauling the brush long distances. The small trees are brought to the still where the usable material is trimmed off. The heavy wood furnishes fuel for the boiler. The spent material after drying is also used for fuel. About five years is required for new growth to reach the desired size.

Procuring the material for the stills involves hard labor which is often performed under severe weather conditions. Considering the labor involved, the returns are relatively small, but they provide additional income without undue interference with the usual farm operations.

The oil is usually brought by the producers to local storekeepers or collectors in some central location where it is cleaned by removal of dirt and water before entering the market. Some producers, however, sell directly to large dealers in essential oils.

Sweet birch and wintergreen. Two native plants yield volatile oils of identical flavor, namely, sweet birch and wintergreen. These oils consist of up to 99% of methyl salicylate to which the therapeutic properties of the oil are due. Methyl salicylate can be made cheaply synthetically, and since it has the same medicinal properties as these natural oils, the U. S. Pharmacopoeia permits its use for medicinal purposes, provided it is labeled accordingly. However, the oils possess certain flavor characteristics not possessed by methyl salicylate, and they therefore are in demand as flavoring agents in certain products. They are used in carbonated beverages, chewing gum and dentifrices. For their therapeutic value they may be used in liniments and ointments, but for that purpose they are probably not superior to methyl salicylate. Neither sweet birch nor wintergreen oils exist in the respective plants as such but are formed when

certain glycosides that are present are acted upon by plant enzymes. To bring about this reaction the plant material used is chopped or crushed and then macerated in warm water in the still, generally overnight, before the usual distillation is started.

The sweet birch or black birch, *Betula lenta* L., is a rather widely distributed tree from New England to Tennessee and Florida. Production of the oil is a very limited industry, carried on chiefly in north central and eastern Pennsylvania,

FIG. 7. Black birch (*Betula lenta*). (*Courtesy New York Botanical Garden.*)

the Connecticut Valley and in the southern Appalachian region of Tennessee and the Carolinas. The trade recognizes two grades of the oil, namely, northern oil produced mainly in Pennsylvania and regions north, and southern oil, produced in the region farther south. It is claimed that the northern oil has a superior fragrance. This preference is reflected in the market value of the two grades. No botanical differences can be discerned between the trees in the two regions, and the physical and chemical characteristics of the oils from the two regions do not provide a basis for this distinction by the trade.

Production of birch oil in five north central Pennsylvania counties is largely a winter activity of farmers in that region who thus utilize the otherwise slack period on the farm to add to their income. The cutting, hauling and trimming of the branches is a laborious task, somewhat less so in winter because it is not hampered then as in summer by the leaves which do not contain oil and only add to the amount of material that must be handled. It is impractical and uneconomical to haul the material more than a few miles, and many of the stills are therefore moved from place to place. Several years are required for the new growth on the cut trees to reach the desired size.

The stills, which are of about 200 cubic feet capacity and hold from 1 to 1½ tons, are constructed of heavy planks made as leak-proof as possible. The bottom is faced with heavy sheet copper so that a fire may be maintained directly under it. The stills are firmly packed full with the small material at the bottom.

If the period of maceration is during the night, distillation is conducted through most of the following day. The yield approximates 0.5% of oil. The oils are heavier than water and therefore settle to the bottom of the receivers which must be designed accordingly. The water which flows from the receivers during the early period of the distillation holds considerable oil in suspension, and this is generally returned to the still with the next charge.

Production of the so-called southern oil is no doubt accomplished in much the same manner. There the distilling equipment is likewise of simple and inexpensive design, and, as in the north, stills are moved from place to place to be accessible to the material needed.

Wintergreen, *Gaultheria procumbens*

L., is a small, low growing, perennial, evergreen herb usually found in cool, damp situations in woods, most abundantly in the mountains of the Eastern States. Production of the oil is centered in Carbon and Luzerne counties, Pennsylvania. Collection of the herb is slow and difficult. The plants are usually partly covered with fallen leaves which must be raked off after which the leaves and small stems of the wintergreen are pulled off by hand and placed in sacks. Since much of the work is under low growing trees its laborious nature can easily be understood. The distillation is usually done in the summer months when the plant contains the most oil and children can be helpful in collecting.

The oil, which is the same as birch oil, as already explained, is obtained by maceration and distillation with the use of similar equipment, similarly operated but generally of smaller size. Most of the stills are of simple, home construction, but there are several of more advanced design. The time required to exhaust a charge is reported to range up to 12 hours. The yield of oil depends on the season of the year, the proportion of leaves and stems and the completeness of the chemical reaction that takes place during the maceration. The average is about 0.5%. The amount of oil produced annually has decreased steadily for years, and at present only a few people are engaged in its production.

FIG. 8. Wintergreen (*Gaultheria procumbens*). (*Courtesy U. S. Bureau of Plant Industry.*)

FIG. 9. Witch-hazel (*Hamamelis virginiana*). (*Courtesy Mass. Hort. Soc.*)

Witch-hazel. Although the witch-hazel shrub, *Hamamelis virginiana* L., contains a volatile oil which has for many years been considered the therapeutic agent in witch-hazel extract used in external medicine, the oil is not produced as such. The product obtained in Connecticut from the witch-hazel shrub is the aqueous distillate resulting from steam distillation of the young branches. To this 15% of alcohol is added. It is an official product of the National Formulary VII in which it is described under the names "witch-hazel water".

"Hamamelis water" and "distilled extract of witch-hazel". No oil separates during the distillation.

There are no farmer producers operating crude equipment, as in the case of most of the oils already discussed. The industry in south central Connecticut is limited to the operations of a few special producers with highly developed modern copper stills using selected raw materials. It is reported that generally 50 gallons of filtered aqueous extract are obtained from 1,000 pounds of brush. To this the alcohol is added, and the product is then stored in oak barrels which are paraffined on the inside. There are no statistics on the quantity of the extract produced.

Acknowledgments

The information for the foregoing discussion was derived from various sources. Some of it is based on correspondence with producers, and credit is due to those who thus contributed to this paper. Dealers in essential oils aided greatly by furnishing the names and locations of producers. Unpublished reports of field investigations of essential oil production made by members of the division at various times were consulted. As stated in the introduction, statistics on the production of these oils are almost entirely lacking. Such figures as can be obtained from various sources are usually incomplete or contradictory and more misleading than useful. The literature on the subject is limited, and some of it is old and unreliable, but much useful information was nevertheless obtained from such sources.

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Utilization Abstracts

Pineapples. Pineapples have previously been reported as growing wild in Brazil, Surinam and Paraguay, and now there is word of their wild state in Venezuela. The forms there bear seeds abundantly and occur in a number of varieties, some of which have been under cultivation by the Piaroa Indians. (*Ismael Vélez, Science 104: 427. 1946*).

Tung Oil—*A Gift of China*

In 1937 the annual maximum of 175 million pounds of this valuable drying oil was imported from China into the United States, and by 1946 constantly increasing domestic production of the oil rose to a little more than 15 million pounds that year.

G. H. BLACKMON

Florida Agricultural Experiment Station

Introduction

In 1905 the United States Department of Agriculture brought the tung-oil tree, *Aleurites Fordii,* from China to the United States and thereby initiated one of the many attempts that have become so important in recent years to make America independent of foreign sources of plant products. The genus *Aleurites* contains five species, *viz.*, *A. Fordii* Hemsl., *A. montana* (Lour.) Wilson, *A. moluccana* (L.) Willd., *A. cordata* Thunberg and *A. trisperma* Blanco, but of them all, *A. Fordii* is by far the most important so far as production of tung oil is concerned. According to reports, however, *A. montana* supplies at least some of the oil produced in the warmer parts of China.

A. Fordii, a native of China, is a deciduous tree and grows 25 to 40 feet and more in height. The leaves are heart-shaped, though often with three more or less distinct lobes, large and dark green in color. The fruit is from two to three inches in diameter, olive green turning to a dark or deep brown when mature and dry. The fruit may be borne singly or in clusters of two or more, according to type, and is generally more or less spherical in shape. The common distinction of types as "single" and "cluster" designates how the fruit is borne, whether one fruit or two or more at the ends of twigs. The fruit, often referred to as a "nut," consists of an outer portion or husk and usually five seeds, sometimes three to seven of them. When mature the fruit falls to the ground and when dry is ready for harvest.

Development in the United States

Since the introduction of the tung tree there have been more than 150,000 acres planted to it in the United States, mostly in Mississippi, Louisiana, Florida, Alabama, Georgia and Texas. The 1940 census shows a total of 12,671,000 trees of all ages in the United States, and there have been heavy plantings since the year of that report.

The first tung seed brought into this country in 1905 were received by the United States Department of Agriculture from Consul General L. S. Wilcox at Hankow, China. These seed were planted in the Department's Plant Introduction Garden at Chico, California, and seedlings were distributed from there to various cooperators. Several times during subsequent years the Department received other seed from China; these, together with seed produced by the first trees grown here, were planted, and many small nursery trees were sent to various parts of the country for testing wherever climatic conditions seemed to offer possibilities for tung tree growth.

Several trees went to Tallahassee, Florida, and in 1906 Mr. William H. Raynes planted five on his plantation

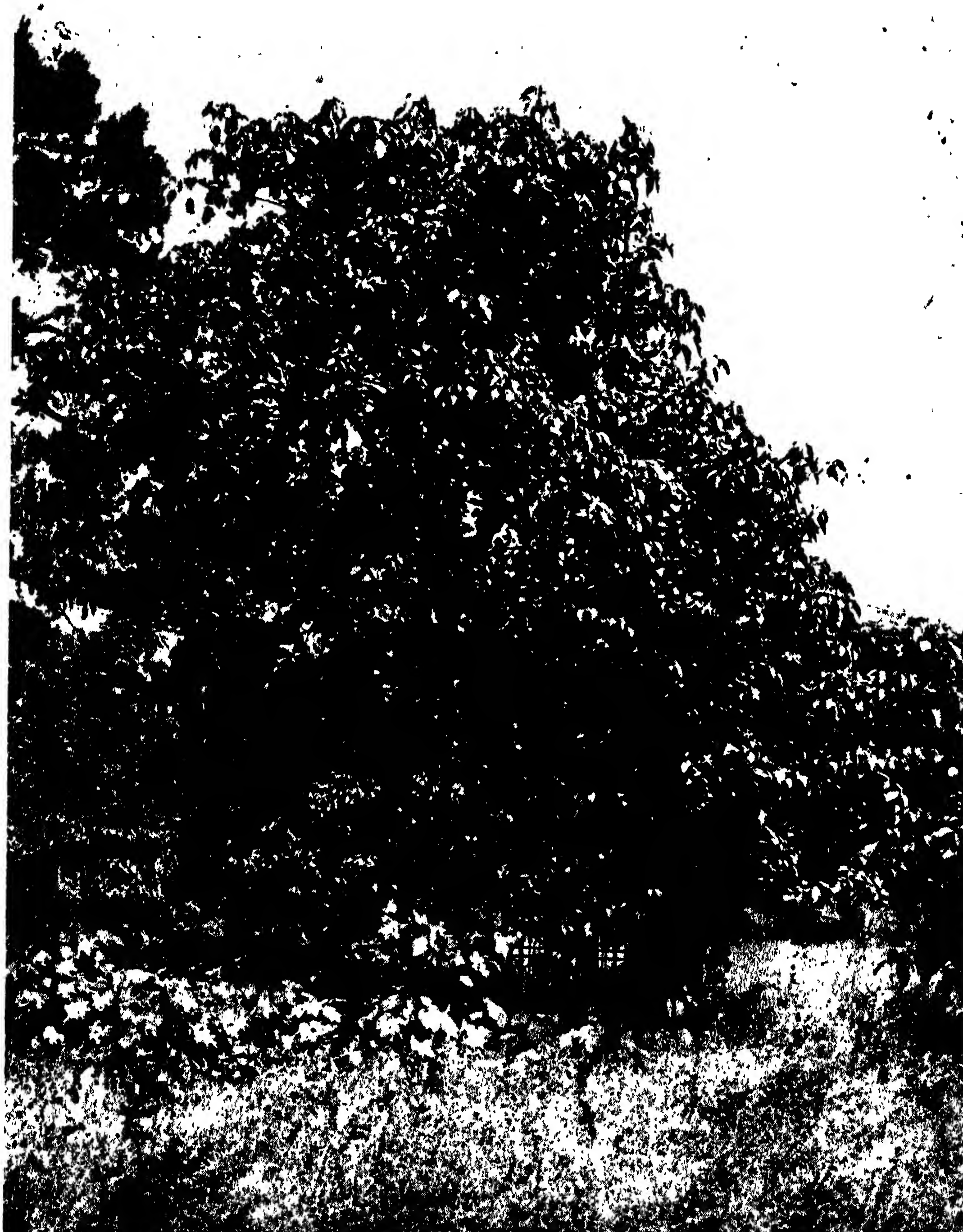

FIG. 1. In 1905 seeds of the tung tree (*Aleurites Fordii*) were first imported from China into the United States by the U. S. Department of Agriculture. Of the seedlings raised from these seeds at the Department's Plant Introduction Garden at Chico, Cal., five went to Mr. W. H. Raynes, on whose plantation near Tallahassee, Fla., they were planted. One of them survived, pictured here, and lived until August, 1940, when it died after removal for road construction.

nearby. One of them survived and lived until August, 1940, when it died after its removal from the right-of-way for a new highway. At the time the tree was removed and replanted it was about 35 feet tall and had a trunk circumference of 5.29 feet. The tree bore three fruits in 1908 and continued to yield each year except when spring frosts destroyed the blooms and during the time it was recovering from damage caused by a fire which destroyed the plantation home shortly after Mr. Raynes died in 1914. In 1913 the Educational Bureau of the Paint Manufacturers' Association expressed 2.2 gallons of oil from 1,095 fruits produced by the Raynes tree, this being the first American-grown tung oil. In 1913 Mr. Tennant Ronalds, near Tallahassee, planted four acres with seed of the Raynes tree and later increased the orchard to 40 acres.

One of the trees distributed by the U. S. Department of Agriculture from the early nursery at Chico, was planted by Mr. J. B. Wight at Cairo, Georgia. This tree is still living and has produced many crops of fruit. There are also several old tung trees in Baldwin County, Alabama, which were evidently planted during the early days of tung trials, as they are now of large size.

The Texas Experiment Station planted two trees in 1907 and two in 1908. It is reported that the first two and one of the second pair lived until January, 1930, when they were killed by a temperature of −4 degrees F.

Early tests of the tung tree at the Florida Agricultural Experiment Station began in 1912 when ten trees were received from the United States Department of Agriculture and planted in the Horticultural Grounds. Some of the original trees died and were replaced in 1914. Certain ones of the first planted trees began to bear in 1916. All these trees are still vigorous and in production, except No. 5, which was killed by the extreme cold of November 15–17, 1940, and No. 10, which was killed by mushroom root-rot in 1945. The average annual yield per tree of air-dried hulled seed from 1922 to 1946 inclusive varied from 5.6 to 65.7 pounds and the amount of oil calculated in the seed from 1.9 to 22.7 pounds. The average for all eight trees was 25.8 pounds of seed and 8.9 pounds of oil for the 25 years.

Soon after 1920, as a result of the ten trees growing on the Experiment Station Grounds, interest began to be manifested in tung culture, and a small orchard was planted near Gainesville, Florida, in 1923. In 1924–25 the American Paint and Varnish Manufacturers' Association planted an experimental orchard in another part of this area, but the land selected was too wet for tung trees and the test was not successful.

Tung Tree in China

The Chinese have been familiar with tung oil for centuries. However, they apparently have given little attention to the culture of the tree, since it could be planted in waste places, such as ditch banks and hillsides, and in due time would produce fruit. No large cultivated orchards have been reported, but apparently some small ones have been maintained.

The tree is said to thrive best in hilly regions where the altitude does not exceed 2,500 feet. This impression may be due to the fact that such hilly sections are the principal locations of plantings, as they more than likely are the waste lands which can not be utilized for more intensive agricultural production. This situation is quite different from that in the United States where trees have always thrived best on good soils and have never succeeded on those with low fertility or in the wild without cultivation.

It has been reported from China that the trees can withstand a temperature

FIG. 2 (*Upper*). A tung tree in full flower in early spring before the leaves appear. FIG. 3 (*Lower*). A tung orchard after the leaves have fallen and the fruits have been gathered in sacks.

of 4° F., but this doubtless refers to *A. Fordii,* as *A. montana* will not survive at such a low temperature in the United States and has been killed to the ground by a sudden fall in temperature to 18° or 20° F. This agrees with the experience in the United States with *A. Fordii,* except that temperatures of 26° and 28° F. have caused damage to trees of all ages when not thoroughly dormant.

The tree in China is said to attain a height of 10 to 30 feet, with a trunk diameter of six to ten inches, and begins to bear in three to six years and to decline in ten years. It is said that the trees pass their maximum producing capacity at about 10 years of age and are replaced by new plants in 12 to 14 years. Yields are said to be from 30 to 40 pounds of fruit per tree annually when at the height of production. These data, as reported for China, show less growth and yields than those obtained in the best producing areas in the United States where tung has been extensively planted.

Reports state that the Chinese farmer clears away a place in the waste land to plant the trees or seed, digs a hole and fills in with compost or some other type of good organic material, and the trees are allowed to grow until the strongest one can be determined; then the weaklings are removed. No additional fertilization and cultivation are given the soil except to cut the vegetation from around the trees to eliminate competition. This may account for the reported short life of the tung tree in China as compared with the prospective age of the tree in the United States where the best practice is to prepare the land before the trees are planted. There is probably some improvement taking place in China, or, at least, there are indications of this, as much of the information regarding cultural practices developed by the Florida Agricultural Experiment Station and other State and Federal agencies have been obtained by Chinese agricultural workers for the express purpose of testing these improved methods under conditions in China.

In China, harvesting the fruit, shelling, grinding the kernel and extracting the oil are quite different from the modern mechanical methods employed in the United States and certain other countries which have undertaken to establish a tung-oil industry. The Chinese practice is to allow the fruit to remain on the ground until the husks decay sufficiently to permit easy removal, when it is gathered and the seed removed. In some cases the fruit is gathered, placed in piles, and then covered with straw where it is allowed to remain and ferment, which accomplishes the desired purpose of getting the husks in such condition that they can be readily removed by hand. The husked seeds are carried in baskets slung on poles to small mills where the oil is expressed by hand in a crude and unique type of wooden press.

The oil is purchased from the small mills by agents and transported in baskets by labor to collection stations or river points from which it is transported to the coasts. By a settling process much of the solid impurities are eliminated. The oil itself is then separated into different grades, with the lightest in color being the best.

When the oil-laden junks arrive at distribution points, the baskets are unloaded by labor where the oil is placed in tanks. Further settling takes place in these tanks and the oil is again separated into different grades, according to color and apparent purity. Formerly the oil was transported to America in oak barrels, but in later years tank steamers have been utilized for considerable quantities in bulk.

Reports indicate that there has been great reduction in adulteration of tung oil in China during the past decade or so. In 1929 the Chinese National Government put into effect an inspection

FIG. 4 (*Upper*). A tung tree in fruit. FIG. 5 (*Lower*). Tung trees planted on a contour with blue lupines as a cover crop.

service of tung oil for shipment to foreign destinations and established specifications based on foreign requirements.

Importance and Uses

Tung oil, being an important drying oil, is utilized in large quantities in a great many industries. For many centuries the Chinese have used the oil in various ways but most extensively in paints and waterproofing materials, as in other countries. Crude grades of it are used to coat the Chinese boat or junk instead of covering it with paint. The residue after the oil is expressed from the nuts is used to make a caulking ma-

terial for boats. This is accomplished by burning the residue to a soot which is then mixed with the oil to form a paste to make the caulking substance.

The Chinese also use the oil in its natural state as a protective covering for houses, furniture and other woodwork. Other uses include waterproofing material for masonry, cloth shoes, clothing, baskets and paper.

In America, tung oil is used in the manufacture of varnishes, enamel paint, floor paint, flat wall paint, paint driers, and to make waterproof or spar varnishes. It is also used in the manufacture of oilcloth and linoleum and for waterproofing cloth and many other articles. The electrical industry utilizes large quantities in making insulating compounds for cables, dynamos, motors and other such uses.

There has been an increasing demand for tung oil in America and other countries, but American industries of various kinds use more tung oil than those of any other one country. Extensive research has resulted in increased use.

Tung oil paints give a glossier finish than linseed oil paints, being much more like enamel in this respect. Therefore, they provide a smooth surface which can be easily cleaned. It is said that they are somewhat more resistant to fungus attacks than ordinary paints.

Tung oil was important in connection with many phases of the war program of the United States and her Allies. Consequently, when the United States became involved in war, steps were taken to conserve the supply of tung oil for war purposes, and to this end the Government had the full wholehearted cooperation of American growers and American industry.

FIG. 6 (*Left*). Cluster-type of tung fruits. In the other known type the fruits are borne singly. FIG. 7 (*Right*). Cross-section of the fruit.

Sources of Tung Oil

The principal geographical source of tung oil has been China. Total annual imports into the United States, according to the Bureau of Foreign and Domestic Commerce, United States Department of Commerce, from 1925 to 1940, inclusive, varied from 83,004,000 to 174,885,000 pounds. From January 1 to September 30, 1941, 25,894,000 pounds were imported.

The existing situation regarding the supply of tung oil stocks for American manufacturing concerns has brought about an abnormal condition with reference to the price of the oil. Conse-

TABLE 1

TUNG OIL IMPORTATIONS INTO UNITED STATES[1] (IN POUNDS)

1925—101,554,000	1933—118,762,000
1926— 83,004,000	1934—110,007,000
1927— 89,650,000	1935—120,059,000
1928—109,222,000	1936—134,830,000
1929—119,678,000	1937—174,885,000
1930—126,323,000	1938—107,456,000
1931— 79,311,000	1939— 78,718,000
1932— 75,922,000	1940— 97,049,000
1941—25,894,000[2]	

[1] From U. S. Dept. of Commerce, Bureau of Foreign and Domestic Commerce.
[2] January 1 to September 30.

quently, tung oil is now selling at a price much higher than that received before the war. From 1923 to 1929 the price of imported oil averaged about 12 cents per pound; after 1929 the price began to decline until it reached a low of about four cents per pound in 1933 and 1934. After this there was some increase which was only slight until about 1938 when the price was much higher than that received from 1923 to 1929.

Fruit grown in the United States now furnishes only a small part of the oil required by American manufacturers. However, the supply is gradually increasing, and the U.S.D.A. Crop Reports estimate the 1946 production in the United States at 47,300 tons of fruit which should have yielded approximately 15,136,000 pounds of oil. The estimated yield in 1946 is 28% greater than the 1945 production.

TABLE 2

TUNG FRUIT (NUTS) PRODUCTION IN UNITED STATES[1]

Year	Alabama		Florida		Georgia	
	Tons	Value	Tons	Value	Tons	Value
1939	20	$ 900	550	$ 22,000	15	$ 700
1940	200	13,000	4,700	282,000	1,200	77,000
1941	350	33,000	2,250	202,000	650	60,000
1942	500	47,000	3,700	333,000	950	89,000
1943	100	10,000	700	65,000	200	19,000
1944	700	70,000	7,000	700,000	800	75,000
1945	1,140	117,000	8,400	823,000	1,100	102,000
1946[3]	1,300	134,000	10,500	1,029,000	1,500	144,000

Year	Louisiana[2]		Mississippi		United States	
	Tons	Value	Tons	Value	Tons	Value
1939	150	$ 600	425	$ 1,900	1,160	$ 48,600
1940	1,200	66,000	3,700	222,000	11,000	660,000
1941	1,800	164,000	3,700	314,000	8,750	773,000
1942	4,000	384,000	7,200	684,000	16,350	1,501,000
1943	3,260	326,000	1,940	194,000	6,200	614,000
1944	7,550	778,000	10,630	1,106,000	26,680	2,729,000
1945	10,750	1,086,000	15,690	1,538,000	37,080	3,666,000
1946[3]	14,000	1,379,000	20,000	2,020,000	47,300	4,706,000

[1] U.S.D.A. Crop Reports.
[2] Includes some quantities from Texas.
[3] Preliminary.

Soils and Location

It is important that suitable soils be selected on which to locate the tung orchard. Trees have grown best on soils with a friable clay subsoil which may be classed generally as well drained sandy loams of the good farming lands of the South that are moderately acid in reaction. The soils must have good water drainage, and the site of the orchard should have adequate air drainage to avoid undue losses from freezing temperatures which may occur after the trees force into bloom.

The importance of the location of the tung orchard with reference to cold can not be over-emphasized. In certain areas where a mass of cold air is likely to flow in after periods of warm weather and force the trees into growth, losses will be greater than where such is not the case. But within the best areas as to general elevations, there are some locations and pockets of low lands which have poor air drainage, and these dangerous spots should not be planted to tung trees. However, there is a direct correlation between the relative dormancy, growth and vigor of the trees and cold damage. In general it can be said that when tung trees are thoroughly dormant they can stand relatively low temperatures without injury, though there will be some variation between individual trees. Trees in active growth, or those just forcing into growth, are subject to losses during freezing temperature, especially in killing the bloom buds. Yet, tung trees require enough cold for an adequate dormant rest period, and for

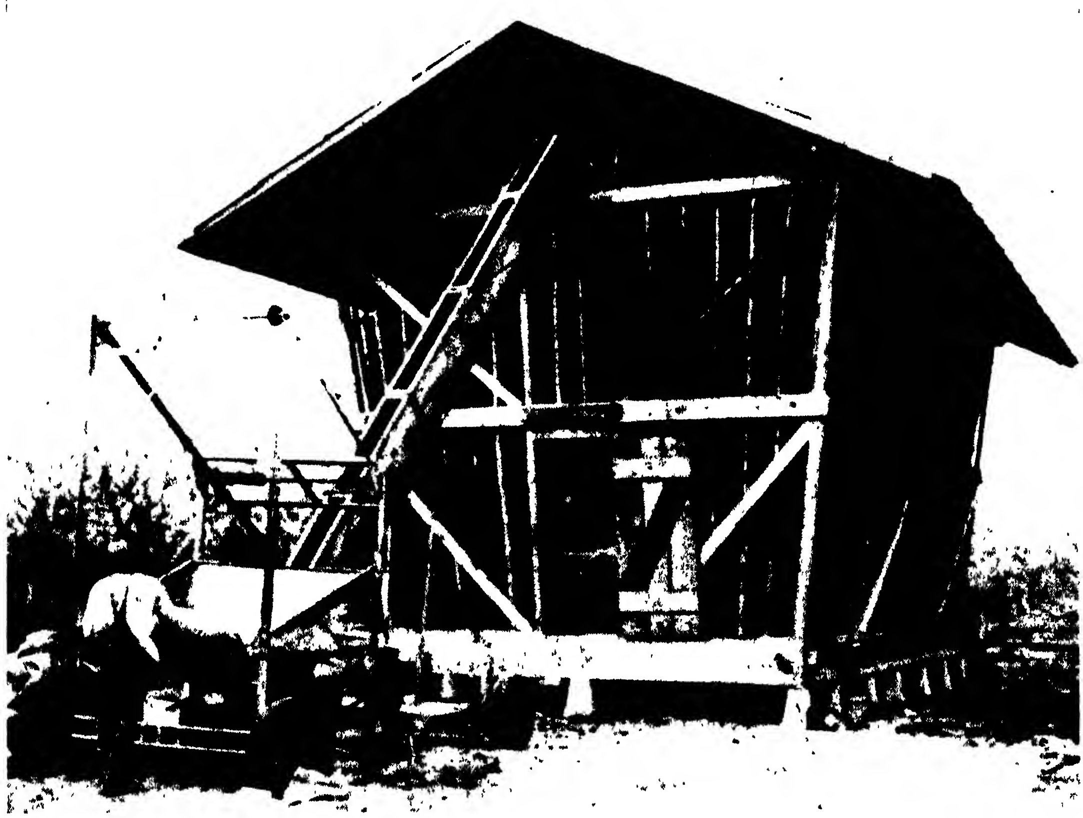

FIG. 8. One type of orchard bin used for storing fruits loose.

this reason they do not succeed in the subtropical areas of the United States.

Planting

Tung orchards have been planted almost entirely with seedling stock, but budded and grafted trees are being tested. Large scale experiments with budding and grafting are being conducted by the U. S. Department of Agriculture, B. P. I., S. & A. E. Tung Investigations Laboratories, and these will supply much needed information as to the possibilities of improving production by asexual propagation. Tests show that prolific trees with the most stable characteristics will transmit such prolificness to a high percentage of seedlings grown from seed produced by such trees. Therefore, growers do not hesitate to plant large acreages with seedling trees grown from seed selected from vigorous and productive trees.

Fertilizers and Cover-Crops

Fertilization and maintenance of soil fertility are of great importance in connection with successful tung culture. Fertilizer experiments have shown that nitrogen and potash are very important in maintaining tung production. The percentages of these will vary under different conditions of soils and of the cover-crops grown and returned. During the first two or three years one-half to one pound for each year of attained age of the trees will generally take care of the requirements. The mixture should contain approximately 8% nitrogen and 8% potash. Most growers, however, apply some phosphoric acid either in the fertilizer mixture or to the land for the satisfactory growth of some good leguminous cover-crop. After trees reach bearing age, they will generally require more potash on most soils, which can be provided by additional applications. When

FIG. 9. Tung oil-expressing machinery, press at left and decorticator at right. (*Courtesy of the Alachua Tung Oil Co.*).

phosphoric acid is applied in the tree fertilizer, the mixture usually contains about 8%, derived from either superphosphate or basic slag. Fertilizers are applied at the rate of about one pound for each year of attained age of the tree. In soils of low fertility the amount of fertilizer should be increased to about two pounds per year of tree age. Trees receiving too little potash will develop a potassium deficiency, and when such deficiency is severe, it will cause early defoliation and result in greatly reduced yields and death of the trees. Regardless of the commercial fertilizer used, growers make a practice of applying the tung hulls and tung cake meal in the orchard, when it is possible for it to be returned from the mill.

In addition to the regular fertilizers containing nitrogen, phosphoric acid and potash, tung trees in many areas require an application of one or more supplements for best growth and production. The lack of certain elements in the soil in which tung trees are growing produces various disorders which are manifested by definite symptoms characteristic of the particular condition brought about by a deficiency of those elements.

The most important of the deficiencies in many parts is that of zinc, characterized by malformation and bronzing of the leaves, shortening of the internodes and development of a rosette, as growth progresses. This physiological disorder made its appearance in tung trees soon after some of the first commercial plantings were made, and it was commonly called "bronzing", due to the color of the leaves. Bronzing causes a weakened condition of the trees, and in cold weather severely affected trees may be killed to the ground. The trouble is corrected by application of zinc sulfate to the soil or to the leaves as a spray. Bronzing threatened to retard seriously the development of the tung oil industry when it first made its appearance but research at the Florida Agricultural Experiment Station determined the cause and evolved methods of control.

Manganese and iron deficiencies have also been identified through research at the Florida Station. Manganese deficiency presents as its most typical symptom a chlorosis in the leaves which has been designated "frenching." It can be corrected with manganese sulfate applied either to the soil or to the tree in a foliage spray. Iron deficiency has been noted only in limited localized areas in a few orchards. It has been rather confined to definite sections in the affected orchards where groups of trees showed the typical chlorosis in the leaves. When severe, the affected trees make poor growth and produce light crops of fruit. Iron deficiency is corrected with iron sulfate applied to the soil in which the affected trees are growing, or sprayed on the leaves.

The Florida Agricultural Experiment Station and the United States Department of Agriculture, B. P. I., S. & A. E., cooperating, have identified two other deficiencies and worked out control measures. One of these is caused by too little copper available in the soil and the other is due to a lack of magnesium. Growth and production are greatly retarded when trees are severely affected.

Severe copper deficiency has been observed in some orchards in the Gainesville and Williston, Florida, areas. The disorder can be identified by a reduction in the size of the leaves, later by defoliation, and in advanced stages by a dying back of the terminal twigs. The development of the cupped shape of the leaves has suggested the name "cupping", by which the deficiency is commonly known. This disorder is corrected by applications of copper sulfate to the soil or in a solution sprayed on the foliage.

Magnesium deficiency has been quite prevalent in certain areas where tung trees are being grown on some of the

sandier soils and, when severe, it affects growth and production. It is characterized by marginal leaf scorch, and in some instances the necrotic areas in the leaf progress inward between the veins, closely resembling symptoms of potassium deficiency. The visible symptoms usually are not evident until July or later. Premature defoliation takes place in late summer on trees severely affected. This deficiency is controlled by applications of magnesium to the soil, and since the sulfate is soluble, it is used for quick results.

Tung trees respond to organic material supplied to the soil, and therefore it is advisable to grow and return cover-crops to the land for best results in maintaining tung production. There are several green manure crops which can be utilized for this purpose, but legumes are best, since they fix and return atmospheric nitrogen to the soil in addition to organic matter produced.

During the first several years after starting the orchard the main area cultivated throughout the summer is a strip the width of a disk harrow on each side of the tree rows. This permits the growing of some satisfactory summer legume, such as *Crotalaria,* Alyce clover and beggarweed.

Winter cover-crops of lupines, vetches and peas are important in tung culture, and they can be grown satisfactorily on lands which have a considerable amount of clay. Soils with little clay and those of a deep sandy nature are generally not adapted for successful growth of these winter legumes, although under some conditions with late planting and heavy fertilization fairly good results can be obtained with some of these crops. These winter legumes give excellent results in the program for the maintenance of soil fertility, since they grow at a time when the trees are dormant and there is no competition with them for the moisture in the soil.

Insects and Diseases

At present there are no insect and fungus diseases of tung trees causing universal losses. There are a few which have made their appearance, but they have not caused serious reductions in production except in localized areas.

Nematodes have caused some trouble on nursery stock when the trees were planted on lands heavily infested with them. However, experimental plantings of heavily infested nursery stock on the Florida Experiment Station Farm grew out of the infestation and, when removed a few years later, were free of root-knot and made satisfactory growth. Therefore, nematodes may cause severe damage to young trees in the nursery and seriously retard their growth during the first year or two, but when the trees are transplanted to the orchard the root-knot disappears.

There have been three scale insects reported on tung trees, none of which has proved serious to date. They are the ivy scale (*Aspidiotus hederae* (Vall.)), latania scale (*Aspidiotus lataniae* (Siga)) and the cottony cushion scale (*Icerya purchasi* (Masc)). If necessary, the first two can be controlled with a dormant spray of lime sulfur or oil. The cottony cushion scale can be controlled biologically with *Vedalia* lady-bird beetle released in the orchard when infestations are sufficiently severe to warrant control measures.

Thread blight (*Corticium Stevensii* (Burt)) has produced severe injury in parts of some orchards, and when severe, causes a dying back of the branches. It can be controlled by spraying with Bordeaux mixture. One bacterial spot (*Bacterium aleuritidis* (McCulloch and Demaree)) of tung leaves has been described, but no serious damage caused by it has been reported.

Mushroom root-rot (*Clitocybe tabescens* (Scop.) (Bres.)) disease has killed tung trees in localized areas in some

orchards. It generally occurs only where oaks and other native host trees have been cleared away to permit planting tung trees.

Harvesting

The methods employed in harvesting the fruit are quite simple. When the fruit becomes fully mature in autumn, it drops from the trees and is generally allowed to remain on the ground until dry, but if drying equipment is available, moist fruit can be gathered. It is picked up by hand and either sacked and placed in covered sheds to dry further or run through dryers and then placed loose in well ventilated buildings erected especially for the purpose. When stored in sacks the sacks are stacked in such a manner that air has free passage between them.

The buildings in which fruit is stored loose in the orchard are so constructed that air has free access from the center outward. This is generally accomplished by erecting a crib-like structure, with poultry netting nailed to the framework so as to leave the sides open for ventilation. Holes covered with wire netting are left in the floor to insure ventilation and also for ease in removing the fruit. These large outdoor bins are built at convenient locations in the orchard where the fruit can be placed in them as it is gathered. Unloading is accomplished with a gasoline engine-powered portable elevator which conveys the fruit from the building into the truck body. Some storage buildings at the mill have forced ventilation, and most of them are equipped with conveyors for transporting fruit to the processing machinery.

Where the fruit is stored in sacks the buildings are generally long open sheds of easy access with the roof about six to eight feet high to allow convenient stacking. The sacks, tied in the orchard, are allowed to remain in these sheds until the time of milling the fruit, when they are loaded onto trucks and transported to processing plants. At the mills the fruit is dumped into large bins convenient to the conveyor belts running to the presses, and the empty sacks returned to the grower.

Care must be exercised to prevent too high a moisture content of the fruit at the time of milling. This is the reason the fruit is allowed to become as dry as possible before it is picked from the ground. It also explains why it is necessary to store the fruit in well ventilated, dry places which, in addition, insure further drying out of any excess moisture. The fruit should not contain too much moisture when it is to be shelled and run through the presses, for when too moist (more than 10% to 12% moisture) the seed gives trouble in the presses, and it is impossible to recover the oil in as high percentage as when the fruit is properly dried. However, many mills are now equipped with dryers with which fruit can be dried to where it will have the optimum moisture content.

The first mill to be built in America, and in the world, for complete modern mechanical expressing of oil from tung seed, was erected in 1928 by the Alachua Tung Oil Company on their property near Gainesville, Florida. This plant initiated commercial production of tung oil in the United States, and the first tank car of American tung oil was shipped from Gainesville, Florida, in 1930, 17 years after the first oil was expressed from American grown tung fruit produced at Tallahassee, Florida. In addition to the mill at Gainesville, there are two others in Florida located at Brooker and Lamont. There are mills also in Georgia, Alabama, Mississippi and Louisiana, at strategical locations which, in connection with the Florida plants, can process the present production of tung fruit in the United States.

These plants contain modern equipment for decorticating the fruit, grinding

the kernels and expressing the oil from the kernels. The decorticator, which is the machine that removes the hull or husk from the seed, consists of a rotary disk and huller. The seeds are delivered from these machines, after decortication, into conveyors in which they are transported to grinders and then to the presses. There the seed-meal passes through the press, generally a screw type, where the oil is expressed under pressure. The oil is then passed through filters for removal of solid matter and for clarifying, and it is then ready to be placed in storage tanks or tank cars for shipment. An average of about 16% (slightly higher in some fruit) of oil on the basis of the weight of the air-dried whole fruit is obtained by the expeller type presses. Thus the average amount of oil recovered is generally calculated to be about 320 to 350 pounds of oil per ton of whole fruit. The fruit, other than that produced by the mill owners, is either purchased from the growers or processed at a designated price per ton.

American produced tung oil is of very high and satisfactory quality. The oil is light golden or light amber in color and is nearly transparent after it has passed through the filters.

The tung cake, which is the residue left after the oil has been expelled, contains various percentages of oil, sometimes as much as 5%, which would be worth several dollars per ton of fruit at present prices if the oil could be recovered. This problem is being investigated in an effort to develop improved methods of expelling or extraction, together with the possibility of extracting the oil from the cake with solvents.

Varieties

Up to the present there has not been any great attempt to introduce named tung varieties. Tree No. 2 of the original ten trees on the Florida Experiment Station grounds has come to be known generally as the "Florida." This is a cluster type and has been the source, directly or indirectly, of considerable acreage in tung in the United States.

Tree No. 9 has been utilized in many plantings and has been so designated, and, while it has not been given a name, it can be considered as a variety and may be given an acceptable name at some future date. It has certainly had an excellent record in point of production and has the ability of passing on to its progeny the vigor and prolificness that make it stand out prominently among tung varieties.

Workers in the United States Department of Agriculture in tung investigations have selected a large number of clones with which they are conducting experiments. These have been chosen as foundation stock with which to carry on their breeding and propagation work.

The tung industry is still in the seedling stage, and it will continue so until methods of asexual propagation are in general use. Especially is this true in face of the fact that it is possible to make selections of certain individual trees which will pass on their prolific characteristics to a large percentage of their progeny.

The tung industry to date has been developed and expanded rather rapidly over a wide area in the South. The pioneer spirit of the American people has again been emphasized, for those who have made these early tung plantings are truly pioneers, just as others have been who paved the way for many other horticultural industries in the United States.

Research

A great amount of research is being carried by the various State Experiment Stations and the United States Department of Agriculture in the commercial tung-producing area of the South. The Florida Agricultural Experiment Station has been active in this field since

1912. The United States Department of Agriculture began testing tung trees in 1905. In 1938 the Bureau of Plant Industry (now B. P. I., S. & A. E.) set up Laboratories for Tung Investigations at the Florida Agricultural Experiment Station, Gainesville, Florida; at Cairo, Georgia; at the Alabama Gulf Sub-Station, Fairhope, Alabama; and at Bogalusa, Louisiana. In the same year laboratories were opened at Gainesville, Florida, and Bogalusa, Louisiana, by the Bureau of Agricultural Chemistry and Engineering.

Utilization Abstracts

Tonka Beans. From 1941 through 1945 Brazil shipped to the United States an annual average of $47,000 worth of tonka beans, the seeds of *Dipteryx odorata*. This tree flourishes in the Brazilian states of Amazonas, Pará and Mato Grasso, sometimes attaining a height of 100 feet. The fruit is a pod, about two inches long, mahogany in color when ripe, and contains a single shiny black seed. This seed or bean is known in Brazil as cumarú and is one source of an ingredient known as coumarin which is extensively used as a flavoring agent in the preparation of tobacco, snuff, cosmetics, soaps, perfumes and foodstuffs. It accounts in part for the pleasant fragrance of cigarettes, the delicate scent of toilet soaps and the piquant taste of liqueurs.

Fallen pods are gathered from January to March, the hard outer shells removed and the beans then spread out for two or three days to dry. They are next bagged and shipped in boats or canoes to nearby towns where they are soaked in native rum up to several days. When the rum is drained off the beans are again dried, and this process coats them with a white crystalline deposit of coumarin. They are then ready for export.

For use in cigarette tobacco, the most important use in the United States, the beans are ground and given another rum treatment, this time for about three months. The resulting liquid, rich in coumarin and highly aromatic, is drained off and sprayed over the tobacco, giving it a distinctive fragrance. The extract is used also in cakes, candies, preserves and liqueurs, as well as a substitute for vanilla. It has also been found to be a fixing agent in the manufacture of coloring materials. And medically the bean kernels have value in the treatment of general weakness and nausea. (*Anon., Brazilian Bulletin, Brazilian Gov't Trade Bureau 3(58): 1. 1946*).

2,4-D, a Selective Herbicide in the Tropics. The selective nature of 2,4-dichlorophenoxyacetic acid as a herbicide has found great use in controlling the weeds of sugar plantations in Puerto Rico, and promises to be of similar value in coffee plantations. These two economically important crop plants are unaffected by sprays of the herbicide in concentrations up to 0.3%, whereas many of the weeds interfering with these crops succumb to that or lower concentrations. Some non-graminaceous weeds are immune. This valuable application of a plant hormone has emerged from work at the institute of Tropical Agriculture at Mayaguez, Puerto Rico. The cost of weeding in sugar-cane plantations there has been reduced to 50¢ per acre, so far as chemicals are concerned, by this means, and some of the most serious weeds have been effectively controlled. *J. van Overbeek and Ismael Vélez, Science 103: 472. April 19, 1946*).

Lycopodium Powder. The inflammable, infinitely fine and almost impalpable spores of lycopodium found use during the recent war in connection with tracer bullets and flares. In peace-time they were used for dusting pattern molds, for packing pills, and, since they crackle brilliantly when they burn, as an ingredient in fireworks. Prior to 1942 the chief source of the powder was Japan which supplied 47,698 pounds in the period 1939–1941. (*Anon., Herbarist No. 12 p. 50. 1946*).

Chemical Control of Plant Growth[1]

The latest applications of physiologic principles to the solution of agricultural and horticultural problems involve the use of synthetic hormones to stimulate rooting of cuttings, to effect blossom thinning in fruit production, to prevent pre-harvest fruit drop, to produce seedless fruit, to achieve control of weeds, to break as well as to prolong dormancy, and to bring about other economically important controls of plant growth.

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Introduction

A CHEMICAL revolution is sweeping through the agricultural world. It is unrivalled by any of the previous great advances in agriculture, and perhaps by most advances in the biological field. For the first time, man can change the pattern of growth and development of plants, can retard growth here or speed it there. The growth-controlling hormones and other chemicals now in use are but the crude beginnings.

The present chemical advance in no way lessens the importance of the great developments of the past. Mechanical inventions, such as the steel plow, the drill, the combine-harvester and the cotton picker, were great forward steps in agricultural progress. Even now, agricultural machine development is far from over, and the applications of new machines to problems of production will continue to be important. In agriculture as in industry, mass production—the cultivation of extensive acreage with only a few men—is one of the important consequences of the machine.

Abundance of crops has always been a necessity for the well-being of any nation with an agricultural economy. Once the virgin fertility of agricultural soils approached exhaustion, the matter of artificial fertilizers demanded attention. This was a biological and chemical problem in the control of plant growth. It was discovered long ago that certain elements are essential for the growth of all plants (nitrogen, phosphorus, potassium, calcium, *etc.*), and that some soils are deficient in one or more of these. It was also found that traces of certain other elements (manganese, boron, zinc, *etc.*) are required for the satisfactory growth of many kinds of plants. Such discoveries were the very foundation of the fertilizer industry and have gone far toward making possible the economic production of crops in areas that might otherwise constitute marginal land.

Another great advance in agriculture has been in the field of plant breeding, in which new varieties and strains of plants have been produced which are

[1] This report is a brief résumé of a book soon to be published under the title "Hormones and Horticulture" by the McGraw-Hill Book Company, Inc. Other authors of the book are Elizabeth Bindloss Johnson and Ruth M. Addoms.

high-yielding, disease-resistant, and in many other ways improved for the use of man. Hybridization of corn is an outstanding example wherein the advantages of "hybrid vigor" were made available to the average agriculturist.

The present great advance we interpret as a real chemical revolution in agricultural practice. The application of chemistry to soil fertilization and the protection of crops against the ravages of insect and fungus pests was highly important, though hardly revolutionary. But with the current efforts to regulate growth by the application of minute amounts of synthetic growth-controlling hormones, we enter an important new era.

A little about the background of theoretical research which led to current developments: Twenty years ago a young student at the University of Utrecht, in Holland, was working with his famous father on a theoretical problem in plant physiology. His name was Frits Went, and his father, the late F. A. F. C. Went, was Professor of Botany at Utrecht. One of Went's goals was to find an explanation for the response of plants to light and to gravity. That the above ground parts of plants grow upward away from gravity, and toward light when it comes from one side, had been observed for centuries. Darwin had suggested in 1880 that a chemical substance was involved in the response, and Boysen Jensen showed in 1910 that a chemical substance was indeed involved, a substance which under certain conditions stimulated growth. Numerous researchers contributed other important information, and by the middle 1920's the stage was set for Went's work. His important contribution proved to be a method for detecting the presence of growth-controlling hormones and measuring them. Once such an assay method was available, it was possible to determine the chemical nature of plant hormones, the extent of their occurrence in living organisms, and, most important of all, something of their relation to growth. The time was then ripe for an advance in man's understanding of the regulation of plant growth by hormones.

It is interesting to note that a major share of the fundamental research on plant hormones has been carried out with seedling plants of oats. Indeed, Went's quantitative assay method (published in 1928) is based on the degree of response of oat seedlings to the hormone to be tested.

It is a long but highly significant advance from the theoretical researches on oats to applied problems such as control of flowering, of preharvest drop of fruit and the killing of weeds. This advance would hardly have been possible without the chemical work of Kögl, Haagen-Smit and Erxleben. In 1934 these workers found that indoleacetic acid was very active as a plant hormone. The compound had originally been isolated in 1885 from normal and pathological urines, and first prepared synthetically in 1925. But it remained for Kögl *et al.* to establish its identity as a plant hormone. Indoleacetic acid was never used for practical growth control problems; it was too difficult and expensive to make. Less expensive compounds were in the offing.

Hormones and the Rooting of Cuttings

The discovery in 1935 of several new synthetic hormones by Zimmerman and Wilcoxon, and the success of these compounds in speeding the rooting of cuttings, has made possible significant new techniques in plant propagation. Several commercial preparations are now available and appear under the trade names Hormodin (Merck & Co.), Quick-Root (Dow Chemical Co.), Rootone (American Chemical Paint Co.) and

StimRoot (Plant Products Co.). Chemically speaking, the synthetic hormones in these root-inducing compounds are known as naphthaleneacetic and indolebutyric acids (those discovered by Zimmerman and Wilcoxon). The hormones are mixed in minute amounts with talc and sold in powder form; plant cuttings to be rooted are merely dipped in the powder before being placed in the moist sand rooting medium.

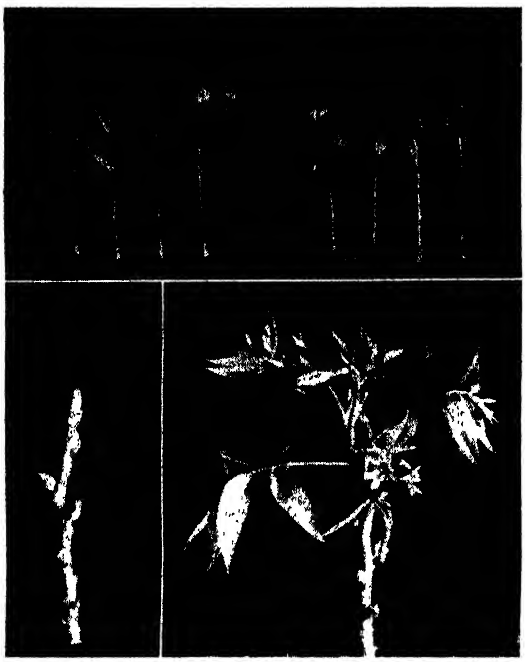

FIG. 1 (*Upper*). Rooting of holly cuttings hastened by hormone treatment. Left, not treated; right, treated with hormone powder; both pictured after 45 days in rooting medium. (*Courtesy Boyce Thompson Institute for Plant Research.*)

FIG. 2 (*Lower*). Spring bud-growth in pecan hastened by hormone treatment after a mild winter. Left, twig from unsprayed tree; right, twig from tree sprayed four times with a dinitrophenol preparation. Pictures taken on same day. Sprayed trees leafed-out about two weeks earlier than the unsprayed. (*Courtesy C. W. Van Horn, Arizona.*)

The greatest contribution of hormones to plant propagation lies in their success in bringing about earlier rooting and sturdier root systems in the cuttings of a great many species of deciduous flowering shrubs and broadleaf evergreens. Hormone treatment also increases the percentage of rooting in difficult-to-root cuttings. (Fig. 1.)

In some species, rooting has not been markedly improved by hormone treatment; and hormones are of no advantage, as yet, in the rooting of cuttings of plants which are never known to root without them. But in plants which are slow or otherwise difficult to root, or give sparse rooting, hormones have been such an advantage that nurserymen as well as amateur gardeners now use them widely.

Blossom Thinning Sprays in the Control of Fruit Production in Apple

Most apple varieties (*e.g.*, Wealthy) which are heavy bearers produce their crops in alternate years, thus necessitating a laborious and expensive hand-thinning operation in the year of bearing. Within the past few years chemical sprays have been discovered which will reduce fruit set by killing some of the flowers; this accomplishes both fruit thinning and more even yearly bearing, and at minimum expense. The work is still in the experimental stage but promises to make an important contribution to control of crop production. Cherries, peaches and other fruits, as well as apples, are now the object of investigation with blossom-thinning sprays.

The first tests to determine whether apples could be thinned by spraying the buds or flowers, without at the same time causing excessive leaf and fruit spur injury, were reported by Auchter and Roberts in 1935. Sprays of inorganic compounds were not effective, but cresylic acid and a tar oil distillate showed promise. Since that time a number of different compounds have been tested, and at present Elgetol (sodium 2,4-dintro-*o*-cresylate, of Standard Agricultural Chemicals, Inc.), and DN Dry Mix Nos. 1 and 2 (40% 2,4-dinitro-*o*-cyclohexyl phenol and 40% 2,4-dinitro-

o-cresol, respectively, of the Dow Chemical Co.) are most widely used in experimental work. The synthetic plant hormone, naphthaleneacetic acid, also promises to be effective in blossom thinning.

Present experiments indicate that thinning is most successful when sprays are applied to trees in full bloom. At this stage the center flower in each cluster has been pollinated and fruit development initiated. The remaining flowers in the cluster, those in full bloom when sprayed, fail to set fruit. Such treatment results in about 20% of the flowers setting fruit. In the apple variety Wealthy, only 5% of the flowers must develop into fruits to produce a full commercial crop. This means 20 to 25 fruits per 100 blossoming spurs, after the June drop.

The most striking use of thinning sprays is in the control of biennial bearing. Heavy bearing varieties, such as Wealthy, Yellow Transparent and Golden Delicious, if adequately thinned in the "on" year give a full commercial crop in the succeeding "off" year.

The major benefits reported from the use of thinning sprays on apples are decreased orchard costs and greater income from fruit as a result of control of biennial bearing; other advantages are increased yield of fruit, improvement in the color of the red varieties, and better pest control.

Thus far, standard treatments have not been established for most commercial varieties of apple; Wealthy is the outstanding exception. However, the basic experimental work is well in hand, and only trials by the average grower can determine the usefulness of this new horticultural tool.

Control of Preharvest Drop of Fruits with Hormone Sprays

Crop losses as a result of premature drop—before the fruit ripens—may be quite serious for a number of fruits, for example, apples, pears, apricots, plums, peaches and oranges. The preharvest drop of apples may be as great as one-fourth to one-half the entire crop, and the drop may occur before the fruit has matured or developed good color. Under such conditions the grower must either risk a heavy fall of fruit or pick before the best quality and color are attained. (Fig. 3, 4.)

The fall of fruit and leaves is brought about by the separation of a special group of cells, the abscission layer, which is located where the fruits or leaves are attached to the stem.

That abscission could be delayed by spraying with synthetic plant hormones was first reported in 1939. Hormone treatment (dusts or sprays) is now used successfully and on a large scale in preventing preharvest drop of apples and pears, and fruit can be kept on the trees until mature. Thus far the treatment has not been extended to other fruits with complete success, but holly and a few other ornamental evergreens can be successfully treated to delay falling of leaves and berries for 10 to 14 days after cutting.

Numerous commercial hormone preparations for control of preharvest drop of apples are now obtainable: Apple-lok (Westville Laboratory), App-L-Set (Dow Chemical Co.), Fruitone (American Chemical Paint Co.), Hormex (Jean McLean Chemical Co.), Niagara-Stik (Niagara Sprayer and Chemical Co.), Parmone (E. I. du Pont de Nemours & Co.), Stafast (General Chemical Co.) and Stop Drop (Sherwin Williams Co.) are some of the compounds available. Most of these contain the potassium salt of naphthaleneacetic acid and are effective on such common varieties as McIntosh, Duchess and Delicious. Naphthaleneacetic acid is not so effective as 2,4-dichlorophenoxyacetic acid for control of preharvest drop in the

FIG. 3 (*Upper*). Pre-harvest drop of apples from unsprayed tree.

FIG. 4 (*Lower*). Absence of pre-harvest drop of apples from tree which received hormone spray. (*Courtesy Mass. Agr. Exp. Sta.*)

Winesap. Much experimental work remains to be done, both as to varieties and as to kinds of compounds. Dusts are easier and less expensive to apply, and fully as effective as sprays.

For large-scale application of hormones, airplane spraying is proving to be satisfactory. (Fig. 5.)

To be effective, the hormone must be applied before the dropping is well underway. Fruit should not be left on the tree so long after spraying that it becomes over-ripe, nor should the amount of hormone used be so great that fruit is "stuck" so tightly that the next year's fruiting spurs are injured during picking.

FIG. 5. Airplane application of hormone spray to apple orchard, two minutes per acre. (*Courtesy Central Aircraft, Inc., Yakima, Wash.*)

Hormones as Aids to Fruit Set and to Seedless Fruit Production

Pollination of the flower is essential to the formation of fruits of most kinds of plants. Occasionally, however, fruits develop normally without pollination and may then be seedless. Since pollination is dependent upon insects, wind and other climatic conditions, and even upon manual operations in some plants, it is highly desirable to possess a means for achieving the effects of pollination and subsequent fruit-set simply, and at will. This has been accomplished for several kinds of plants by the use of hormones.

Hormone-induced fruit-set is particularly important in improving the production of such greenhouse crops as tomatoes, where inadequate pollination in the winter season often results in light yield of fruit. Besides assuring fruit set, hormone treatment if correctly timed will result in seedless fruit.

Relatively few fruits are naturally seedless (*e.g.*, banana, navel orange,

seedless pear and grapefruit, grapes, Chinese persimmon), but hormone treatment may make possible many new kinds of artificially induced seedless fruits. Experimental work has only begun.

The first record in scientific literature of the use of specific hormones to produce mature seedless fruit is that of Gustafson in 1936. Howlett later suggested the use of chemicals to supplement the normal processes of pollination and fertilization in greenhouse tomato production.

To date, naphthaleneacetic acid has been the most widely used synthetic hormone for inducing seedless fruit, but Howlett recommends a mixture of indolebutyric and naphthoxyacetic acids, which has been widely tested by commercial greenhouses in Ohio the past two or three seasons. Thus far, application of hormones in water or emulsion sprays, or in aerosols, has proved best. The commercial preparations now available are Seed-less-Set (Plant Products Co.) and Fix (Thompson Horticultural Chemical Corp.); full directions for use accompany the products.

The time for application depends in part upon the effect desired; for seedless fruit in tomato, for example, the hormone should be applied before there is any danger of pollination (up to the time the flowers are completely open); for insuring fruit set in the greenhouse without special attention to seedlessness, the spray should be applied after the first flower of a cluster opens; second and third sprayings should be made at intervals of a few days during the blooming of the cluster. Spraying when several blossoms of a cluster are open gives more uniform sized fruits.

While the only real success has been with tomato, other fruits have been made seedless, and fruit set has been improved. In holly, a species where two plants of opposite sex are ordinarily necessary in order to obtain a set of fruit, berries may be produced by applying hormone sprays to the female flowers.

The main advances in seedless fruit production will come when the pomaceous fruits, berries, cherries and plums, can be made seedless by hormone sprays on a large scale. Before certain fruits will be improved, however, it will be necessary to dispense with the seed coats; in "seedless" watermelons, for example, the remaining empty "shell" of the seed is often as large as the normal seed. Seedless cherries and plums will be of no advantage unless some way is also found to prevent the "pit" from forming.

The extent to which hormones will be used commercially for assuring fruit set, or for seedless fruit production, will doubtless depend upon the discovery of new methods (and perhaps even new hormones) that will assure the results desired. Ultimately the increased value of the crop would have to be such that the added expense is worthwhile.

Hormone Treatment of Seeds

The idea of treating seeds with growth hormones of various kinds followed in the wake of their successful use in the rooting of cuttings. The procedure has been to apply hormones to dormant seeds, generally as a dust.

The objectives have been as follows: 1) to increase percentage of germination; 2) to increase rate of germination, especially of those seeds in which germination is normally delayed; 3) to counteract deleterious effects of fungicides; 4) to accelerate the growth rate of the plant and hence advance the date of maturity; 5) to increase yield, whether of a root, foliage or fruit crop.

To date, in spite of the excellent objectives, the results of seed treatment with hormones are largely negative; the German workers, Amlong and Naun-

dorf, are the only ones reporting widespread success. There are scattered cases where a mixture of hormone and thiourea increased the percentage of germination.

The most promising use of hormone treatment of seeds, thus far, is in combination with fungicides; such treatments are based on the theory that certain fungicides may suppress germination by inactivating the naturally occurring hormones in seeds. Even this work remains to be demonstrated beyond question. The most dramatic objective of seed treatment, that of increasing the entire subsequent growth and yield of plants by applying hormones to the seeds before planting, has not yet been realized. It appears that the natural supply of hormones (and/or vitamins) in seeds is adequate for germination and growth, and added amounts are of little or no advantage.

Not only is there scant evidence that hormones stimulate seed germination and subsequent growth, but there is abundant evidence that the synthetic hormone, 2,4-dichlorophenoxyacetic acid (2-4-D), will destroy many kinds of seeds, even when present in only minute amounts. Indeed, sterilization of soil on a field scale by treatment with small amounts of 2-4-D is one of the most promising new methods for weed control.

Hormones and Miscellaneous Growth Phenomena

Control of time of flowering. This objective, if widely realized, would probably do more to control the time of picking and marketing certain crops than anything we now know about. It was first shown in 1942 that spraying strawberries with the synthetic hormone naphthaleneacetic acid would retard flowering by three weeks, thus extending the picking and marketing season. And from Puerto Rico comes the report of van Overbeek that fruiting can be completely controlled in the Cabezona variety of pineapple. This variety ordinarily flowers sparsely, the entire flowering and fruiting period sometimes extending over a period as long as five years. However, a simple treatment of the growing tip of the plant with naphthaleneacetic acid or 2-4-D in minute amounts (0.005 to 0.01 per cent, in any month in the year) will bring plants into flower in about two months; mature fruits may be harvested about five months later. Thus the harvest period of Cabezona pineapple may be fully controlled. What was a disadvantage with an otherwise good quality variety was turned to an advantage with hormone treatment.

Ripening of fruit. Mitchell and Marth have reported that bananas, apples and pears, if picked while green, may be ripened by dipping in dilute solutions of 2-4-D; fruit so treated will ripen five to eight days ahead of the untreated fruit. Tomato did not respond to the treatment.

Hormones and transplanting. Transplanting trees, shrubs, and even herbaceous plants, often results in serious wilting and slow recovery, or occasionally in failure to survive at all. Because hormones are known to promote the rooting of cuttings, the idea has developed that they may also hasten the growth of new roots on transplanted plants. If so, they would stimulate resumption of normal growth rates and increase the numbers of individual plants which survive transplanting. Experiments along these lines have thus far disclosed no real advantage from hormone treatment. The best that can now be said is that, although there have been a few cases of quicker recovery after transplanting, no permanent improvement in growth results.

Weed Control by Hormone Preparations

One of the greatest single problems of agriculture is that of weed control.

Despite the fact that weed-killing chemicals have been known for many years, they have been relatively little used. Mechanical cultivation, arduous and costly, remains today the chief method of weed control. However, the situation is changing rapidly since the discovery that one of the synthetic hormones (2-4-D) will destroy some plants and leave at least a few others relatively unharmed. For the first time there is promise of revolutionary changes in the whole field of chemical control of weeds. (Figs. 6, 7, 8.)

The substances which have proved most useful so far are derivatives of phenoxyacetic acid. Unlike most other chemical weed-killers, which are usually plant poisons and are used in concentrations of 1 to 10 per cent, these derivatives of phenoxyacetic acid bring about hormone-like growth-stimulating effects when applied at concentrations of 0.0001 to 0.001 per cent; applied in sprays at concentrations of 0.1 to 0.2 per cent they act as plant killers of a new kind. The chemical penetrates the plant rapidly and becomes distributed throughout its tissues. Leaves and roots wither and die, usually in three weeks or less. Applications should be made in warm weather when plants are growing rapidly, and the killing seems to be more effective when treatments are made in the early part of the day. Plants growing in the shade often are unaffected by 2-4-D treatment, whereas the same kind of plant growing in full sun may be killed with one application.

The best established use of 2-4-D thus far is in the control of lawn weeds. Lawns of blue grass or mixed grasses are not harmed by 2-4-D, and when sprayed with the chemical in a 0.1 per cent concentration, common weeds are destroyed (broad- and narrow-leaf plantain, dandelion, chickweed, *etc.*). The chemical should not be used on vegetable and flower gardens, for most garden plants are injured or destroyed, just as are the lawn weeds. Numerous shrubs are also injured by it, but not in the low concentrations which might drift in the wind at the time lawns are sprayed.

The agricultural uses of 2-4-D for weed control are in their infancy. The relative immunity of most kinds of grasses to 2-4-D carries over to the cereal grasses; wheat, barley, corn, oats, rice and sugar cane growers are among those who stand the greatest immediate chance of benefiting, as well as those who grow grass for seed. Most of the important weed infestations in these crops can be controlled with 2-4-D, not only without injury to the crop, but with resulting increases in yield as a result of weed-free fields. Rehabilitation of pastures weedy from over-grazing is also a promising use for 2-4-D.

Power line rights of way present a major problem in keeping down weed trees and undergrowth, and 2-4-D may well provide the answer; roadsides and railroad rights of way also present major weed control problems. In no case should the possibility of injury of field crops adjacent to such areas be overlooked.

A further important line of investigation of weed-killing uses for 2-4-D lies in its possibilities for soil "sterilization". Preliminary work indicates that when applied to bare fields it will destroy the seeds of many common weeds, and crops can be planted after the harmful effects of the 2-4-D are over. Up to now, however, this procedure seems to have its limitations in regions where there is little rainfall, or where rainfall is sharply seasonal.

For work in the field of health, 2-4-D weed killers have great promise. The common and giant ragweeds, hayfever-causers extraordinary, are easy prey to 2-4-D sprays, and applications are lethal almost up to the time the ragweed be-

FIG. 6 (*Upper*). Wild mustard and grass planted in two pots, the left one sprayed with 2-4-D on March 18. FIG. 7 (*Center*). Two days later. FIG. 8 (*Lower*). Two weeks later. (*Courtesy The Dow Chemical Co.*)

gins to loose its pollen to the wind. Plants which cause skin allergies upon touch, such as poison ivy and poison sumac, are also killed by 2-4-D, but with these plants the chemical is not always effective. Because poison ivy frequently grows in the shade, it presents a special problem; the esters of 2-4-D are more effective than the acid in such cases.

Breaking Dormancy with Chemicals

This subject is no longer new, nor are dormancy-breaking chemicals strictly hormones in the presently accepted sense of the term.

It has been known for a long time that the buds of many kinds of plants are dormant for some weeks or months after their period of active growth. Whether a bud is an "eye" of the potato or the winter bud of the lilac, its growth does not continue with equal intensity throughout the year, even though temperature and other factors remain favorable. Buds of most deciduous trees, for example, are dormant for several months in the late summer, autumn and winter, after cessation of the spring and early summer growth. This rest period apparently is brought on by chemical changes in the buds, presumably by accumulation of chemical substances which slow down metabolism and inhibit growth. It is only buds which are in this dormant state, not entire plants. In nature a few weeks or months of cold weather usually serve to break the resting condition of the buds.

Within the past two decades work has been in progress by Denny, Guthrie and others, chiefly of the Boyce Thompson Institute, which shows that ethylene chlorohydrin (and a few other chemicals) can act as chemical substitutes for cold in the breaking of dormancy. Their work has been on potatoes, gladiolus corms and a number of ornametal shrubs and trees. With their methods the period of dormancy can be shortened by one to three months as a result of ethylene chlorohydrin treatments (azalea, three weeks; deutzia, six weeks; flowering crabapple, eight weeks; hawthorn, four weeks; weigela, five weeks, *etc.*). Freshly harvested potatoes treated with ethylene chlorohydrin will sprout about two months before untreated potatoes, and certain varieties of gladiolus gain one to many months by treatment.

The chief opportunity for large-scale use of methods for breaking dormancy in trees is in mild climates where in many winters there is insufficient cold weather to assure the natural breaking of dormancy, e.g., peach orchards in Georgia and California. The greatest success to date in hastening the breaking of dormancy in orchards has come not from the use of hormones or of ethylene chlorohydrin, but from the use of dinitrophenol and dinitrocresol sprays. Applied in oil (dormant sprays), they shorten the rest period in apples, apricots, cherries, peaches, pears and pecans by at least one to two weeks. (Fig. 2.)

Prolonging or Inducing Dormancy by Hormone Treatment

The work on extending the period of dormancy in plants has thus far been directed chiefly toward preventing sprouting of potatoes in storage, prevention of frost damage to fruit and other trees by holding back bud growth until danger of frost is past, and prevention of sprouting of nursery stock while in storage.

The basic work on prolonging dormancy in potatoes has been carried out, for the most part, by Guthrie and Denny at the Boyce Thompson Institute. Their work shows that treatment of potatoes with the methyl ester of naphthaleneacetic acid as they go into storage will prevent the sprouting which ordinarily starts after a few months. So successful is the treatment in extend-

ing dormancy that such potatoes should not be used for seed.

Hormone treatment of fruit trees, tung trees, *etc.*, in order to delay blooming is still in the experimental stage, but the prospects are good. A delay of a week or two in the flowering of such trees would often prevent great loss by frost damage. It might also make possible the extension of the picking and marketing season.

Hormones have also been used successfully to prevent the sprouting of nursery stock of roses while in storage. The methyl ester of naphthaleneacetic acid holds back bud growth in roses, just as it does in potatoes. It may be applied as a vapor or in a wax-emulsion spray. There are indications that similar treatments may prove equally valuable with other kinds of nursery stock.

Chemical Production of New Varieties of Plants

Colchicine can hardly be considered a plant hormone, yet it exercises an effect on nuclear division which makes it a special chemical of considerable importance. Indeed, because of it the traditional methods of cross-pollinating, and of discovering bud sports, are no longer the only important means of getting new varieties of plants. It is now possible to produce new types by colchicine treatment of seeds, seedlings or growing branch tips of older plants. The proportion of useful new kinds of plants to the total treated is not high, but an occasional new form may more than justify much apparently fruitless work.

Colchicine treatment, when effective, results in a doubling of chromosomes, and the resulting polyploid plants frequently possess size, growth vigor or other qualities more desirable than that of the plants from which they are derived. It has also been possible to render sterile hybrids fertile by colchicine treatment, thus making available new types of plants for ordinary breeding work. One large seed company has introduced a new variety of marigold, and more recently of snapdragon, as a result of its colchicine work; and in all, well over 50 clearly new polyploids have been produced by researchers in this field.

Utilization Abstracts

Buckwheat, Rutin and Hypertension. The discovery in 1860 that buckwheat is a source of the flavonol glucoside, rutin, acquired significance in 1944 when it was found that rutin is effective in the treatment of increased capillary fragility associated with hypertension in man. The resultant widespread and increased demand for the drug led to an investigation by scientists of the Eastern Regional Laboratory in Philadelphia, U. S. Department of Agriculture, for possible sources of this drug which, according to preliminary reports, has been efficaceous in certain cases of retinal hemorrhage and apoplexy. Of all the species examined, buckwheat so far is the most promising source of the drug. The rutin for the first clinical experiments was prepared by them from flue-cured tobacco. The glucoside has been obtained from leaves, blossoms and stems of buckwheat, and a yield as high as 8.56% was reported, considering the whole plant exclusive of roots. It was calculated that an acre of buckwheat in 26 days from planting would produce 14.2 pounds of rutin, and 50.25 pounds, or approximately 3.5 times as much, in 40 days. (*J. F. Couch, J. Naghski and C. F. Krewson, Science 103: 197. February 15, 1946*).

Ragweed. *Ambrosia monophylla* (Walt.) Rydb. (*A. paniculata* Michx.) is cultivated in country gardens in the Dominican Republic and is "used for poultices in the treatment of various pains and ills". It is sold for this purpose in the market places of the capitol city, Trujillo. (*H. A. Allard & H. F. Allard, Science 104: 129. 1946*).

The Role of Botanical Research in the Chicle Industry

An American industry which in the last pre-War year did a total retail business of $140,000,000 and has been based largely on exploitation of the sapodilla forests in the Yucatan Peninsula without much concern for perpetuating the supply.

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Introduction

MAN's propensity to chew—just chew—has resulted in a distinctive subdivision of economic botany, the chicle plants, and has produced a distinctive business activity, the chicle industry. The word "chicle" is a relatively recent addition to our language, and is not included, for example, in American dictionaries on hand, dated 1885 and 1914. Chicle is now defined as the gum obtained from the latex of *Achras Zapota* L., used as the chief ingredient of chewing-gum, and any of several other gums derived from trees of the families Moraceae and Apocynaceae (Webster's New Int. Dict., 2 ed., 1944). For our purposes we can consider chicle as the coagulated latex of *Achras Zapota* and of any other tree used as a basis for chewing-gum, or its synthetic substitute.

For purposes of orientation, we shall briefly consider chicle as a product from plants, chicle as a masticatory for man, Central American chicle as a basis for an industry, and some current trends in American industrial research concerning chicle. This orientation is followed by a conspectus of the past chicle research carried out by private organizations, government and industry, comprising data offered as a historical record of these earliest phases of investigative activity. The paper concludes with an evaluation of future research, pointing out the fields where investigative work might prove advantageous. In all these discussions, it is my purpose to present the chicle problem as a facet of economic botany, in the perspective of its rôle in human activity and in American industry. The economic importance of research will be given special emphasis. It is not the plan of this article to present the botanical details of chicle investigations.

Chicle as a Product from Plants

There are various ways of grouping and relating the products obtained from plants. Each has its own merits. We may classify such products by their chemical constitution (fats, carbohydrates), by their physico-chemical organization (solutions, emulsions), by the tissues from which they are derived (xylem, resin canals, latex tubes), by the phytophysiologic processes concerned

[1] The author wishes to acknowledge the appreciated assistance of R. L. Wilson (Director of Research, Wm. Wrigley Jr. Co.) and R. K. Phelan (Asst. Research Director, Beech-Nut Packing Co.) who checked the manuscript for factual errors, and who offered valuable suggestions. The opinions expressed in this paper, however, are solely those of the author, and do not necessarily represent those of the industry, or of this journal.

The author also wishes to be recorded as not favoring the policy of this periodical in capitalizing the first letter of certain specific scientific names.

(bleeding, guttation), by a laboratory process (solution from tissue by solvents), and by other means. For certain purposes in economic botany, it is well to refer all those substances which are discharged through small pores and openings, and which accumulate on the external surfaces, of plants, as "exudates". Strictly speaking, exudates accumulate naturally through normal physiologic processes or by normal accidents (bark injury). That such exudation may be greatly amplified by man (turpentine and rubber tapping) does not change the nature of the exudate. Likewise, we can still speak of "exudates" if they are obtained by maceration of plant tissues and extraction by solvents.

Five major kinds of exudate may be recognized: (*a*) Liquid water, exuded by guttation from hydathodes, which are leaf pores in close proximity to the ends of xylem vessels, or exuded by secretion from special glands not associated with xylem vessels. (*b*) Saps, exuded by bleeding from broken stems and branches, especially in spring in temperate regions. They are usually derived from xylem tissue, sometimes from phloem, and contain carbohydrates and various other substances. The maple sugar industry in northeastern United States is based on this phenomenon. (*c*) Gums (not including chewing-gum), exuded from stems, branches and fruits. They are amorphous complex carbohydrates which are soluble or which soften in water but not in alcohol. The best known are gum arabic from *Acacia* and *Prosopis*, gum tragacanth from *Astragalus*, and cherry tree gum from *Prunus* and *Cerasus*. They are used in medicine, confectionery and adhesives. (*d*) Resins, exuded from stems, branches and fruits, and often from special resin canals. They are non-crystalline compounds, frequently oxidation products of essential oils, which are soluble in alcohol but not in water. The best known are African copals, Asiatic damars, New Zealand kauri resin, fossil amber, crude turpentine, Canada balsam and frankincense. The insect-derived lacquers and shellacs are chemically related and usually included among resins. Resins are used in varnishes, cements, medicine, incense and naval stores. At times, natural exudates include mixtures of both gums and resins, known as gum-resins, examples of which are asafoetida and myrrh. (*e*) Latices, exuded from broken surfaces of all parts of the plant body. They are complex milky emulsions of granules of various substances suspended in a watery medium in which numerous other substances are also dissolved. The granules include resins, oils, proteids and starch grains. Latex is secreted in special laticiferous tissue, usually in the phloem. This tissue may be composed either of branching coenocytes, which elongate with growth of the plant but do not anastomose, or of anastomosing vessels, formed from the breakdown of the separating walls of individual cells. The families known to bear latex include Apocynaceae, Asclepiadaceae, Campanulaceae, Compositae, Euphorbiaceae, Moraceae, Papaveraceae and Sapotaceae. The best known commercial products from latices are rubber, adhesives, insulating materials, chewing-gums and opium. We are now concerned only with the chewing-gums, obtained originally from the Sapotaceae, but now also from plants of other families, especially the Apocynaceae. Chicle is thus the intermediate commercial product, a stage between the liquid latex of the living tree and the manufactured chewing-gum.

Chicle as a Masticatory for Man

There are various ways of grouping and relating plant products used by man for his own specific purposes. One such group of miscellaneous substances

is known as "masticatories". A masticatory (Fr. *masticatoire;* Span. & Ital. *masticatorio;* Germ. & Dutch *Kaumittel*) is often defined as "any substance that is chewed to increase the secretion of saliva". The rôle of salivary secretion, however, is quite incidental to the act of chewing, and the word might better be defined as "any substance or substances chewed, without intent of ingestion". Narcotic, gustatory, cosmetic, nutritional or other effects may occur concomitantly.

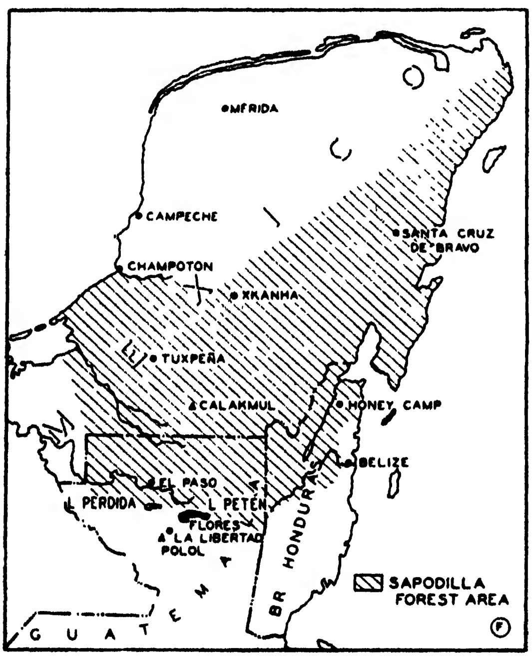


FIG. 1. Area on the Yucatan Peninsula covered by the sapodilla forest (after Lundell).

The study of masticatories, as a field of human knowledge, is still unorganized. A survey of the leading American and European encyclopaedias showed that in no case has a separate article been written on the subject, that the word is generally not indexed, and that at the most only a dictionary definition is included.

The masticatory process, other than that associated with the purposeful chewing of food, is to be allied to various other random and irrelevant movements of man and woman. Such undirected automatisms include incessant and repetitive talking, doodling in all its ingenious manifestations, nail-biting, whittling, foot swinging, fiddling with objects, and the host of other activities that we frequently attribute to "nervousness" and "tension". An understanding of such movements lies in the realm of the psychologist, and the relatively limited research in that field will be mentioned later in this paper. From the cosmopolitanism of the chewing habit, it would appear that such "jawing" and "chawing" is an inherent activity of *Homo.* The action expresses itself in the primitive oborigine chewing an unknown exudate from a jungle tree, as well as in the tailored attorney offering "cocktail chewing-gum" to the debutante of today. Likewise, it expresses itself in the nipple-sucking nursling, through the days of osculation, on into the denture-doodling octogenarian.

Masticatory substances include a vast variety of plant materials, in many countries and among many races. The substances used are of infinite number, varying from raw gums, resins and latices to the finished products of modern industry. In the course of cultural development, certain masticatories have attained widespread regional use. Thus, in the Near East, one tenth of the entire human race indulges in betel chewing. In this bright and relatively modern practice, one chews a homemade package of betel nut slices (*Areca Catechu* L., a palm), a pellet of lime and some aromatic or spicy substance, all wrapped in a betel leaf (*Piper Betle* L., pepper vine). The lime appears to increase the solubility of certain alkaloids in the nut and thus the physiologic effect of the mixture. The resulting copious flow of saliva is brick red in color, dyeing the mouth, lips and gums. The habit eventually turns the teeth black. Pedestrian

expectoration leaves red spots on the streets, certainly a more colorful result than the drab gum blotches on our own sidewalks and subway platforms.

In western South America the chewing of coca (*Erythroxylon Coca* Lam.) is the custom among at least eight million people. In this habit the leaves are chewed together with a small quantity of lime. Coca leaves contain an appreciable quantity of cocaine, and the resulting narcotic effects are intimately linked with this masticatory habit.

In North America the chewing of tobacco was originally an Indian custom. It received a temporary vogue of questionable elegance in the last century, and then experienced a short revival during the cigarette shortage of World War II.

In the spruce-fir regions of the North, resinous exudates of the conifers are used locally. Thus, "balsam gum" (*Abies balsamea* (L.) Mill.) is known in America, Kauharz in Germany, and similar products in Scandinavia and Russia.

From Central America comes the original chicle, a tasteless, highly cohesive, non-narcotic, non-nutritional, coagulated latex, which appears to satisfy in man nothing but his psychologic urge to chew. The original chicle came from a tree known variously as zapote, chicozapote, níspero, sapodilla, *et al.* Botanically the tree has been known as *Achras Zapota.* It is still known by that name in the trade, although the binomial has been changed and other species have been split from it. Adulterants and substitutes have been used, not only from Central America, but from South America, Africa and the Orient, often unrelated botanically to the original *Achras.* The term "chicle" is thus used in both narrow and broad senses. The raw latex is coagulated, processed, combined with other substances, flavored and sweetened, and the finished product is marketed as "chewing-gum." Our interest in chicle, therefore, is that it is the chief constituent of chewing-gum, basis of an American-born industry and an American product, and the use of which was spreading into other countries even before the recent War greatly accelerated that spread.

Central American Chicle as a Basis for an Industry

The chicle demands for chewing-gum production have built up, within the past half century, a huge industry which in the last pre-War year did a total retail business of $140,000,000. At five cents a pack, this figure impressively expresses the more refined chewing propensities of the human race. The chicle industry is curious and interesting in many ways. It is an exploitation industry, "mining" the existing material resources, under circumstances where renewal by further growth is negligible or entirely non-existent. Production is continued largely by discovery of new virgin areas and of new sources. As such, the latex industry has no bright future, if any at all, although the inevitable end to the draining-of-the-bucket may be postponed by sundry "conservation" measures. We shall sketch certain phases of this industry under five headings: (*a*) the geographic aspects; (*b*) the forest and the tree; (*c*) the latex; (*d*) the chiclero; and (*e*) the administrative organization.

The Geographic Aspects. The chicle industry is primarily American in its finances and administration, but pantropical in its field activities. The sources of gum have been, and are, relatively numerous. Jelutong (*Dyera*, Apocynaceae) comes from the East Indies and Malaysia. Sorva (*Couma*, Apocynaceae) and balata, pendare and massaranduba (*Mimusops*, Sapotaceae) come from Brazil, the Guianas, Venezuela and Colombia (Vander Laan,

1927). *Ficus* (Moraceae) from Africa may soon become a significant source. Chilte (*Jatropha,* Euphorbiaceae) is from Mexico at middle latitudes. The original chicle, however, is from a relatively restricted area on the Yucatan peninsula of Central America, comprising parts of Mexico, Guatemala and British Honduras. In each general area there are various substitutes and adulterants. Pre-War imports of jelutong into the United States exceeded those of chicle for the years 1937–1941. The War entirely eliminated the supply from the Far East, and manufacturers made up the deficit by increasing the purchases of true chicle and by utilizing the South American gums (Overley & Griffith, 1946). A small amount of jelutong was imported in 1946 but only from pre-War supplies that had been stored under water to prevent oxidation and spoilage.

The relatively small Yucatecan area in Central America has been—in the history of the industry—the chief and most reliable source of chicle. This publication is concerned specifically with that Central American region and treats only incidentally of the industry in other regions. Geologically, the Yucatecan area is a limestone plateau, seldom more than 200 meters (650 feet) above sea level. It is essentially flat. Streams and lakes are scarce, although in the

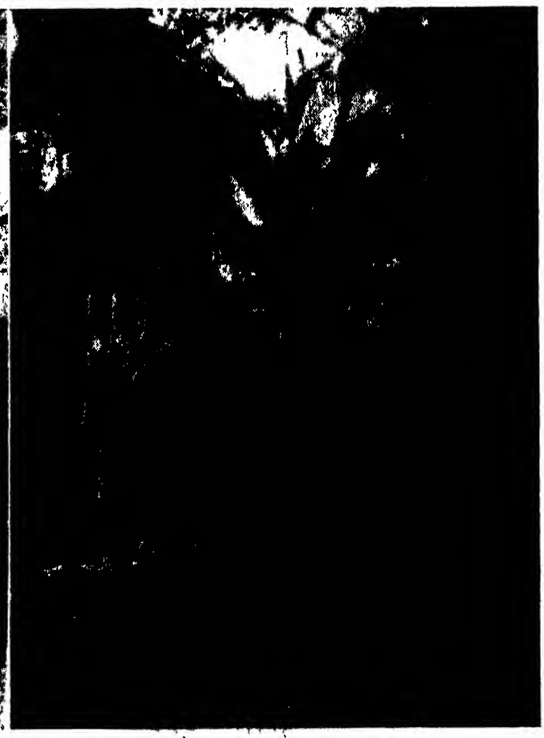


FIG. 2. (*Left*). The effect of mule "grazing" in northern British Honduras. Because of the absence of suitable grasslands for forage, the chiclero, or latex collector, feeds his animals on the leaves of the ramón tree which he either cuts down or climbs to lop off the branches. The tall tree at the left center has been pruned for this purpose; the tree at the right center has not yet been shorn.

FIG. 3. (*Right*). A forest of cohune palm (*Orbignya Cohune* (Mart.) Dahlgren) on deep and fertile soil. Such sites in northern British Honduras are most suitable for agriculture and for forest plantations. The nuts of the cohune palm yield an oil, similar to that of the coconut, which is becoming of increasing importance.

rainy season swamps may predominate over vast areas.

Climatically, the region is characterized by a dry season extending from February to June, with a total annual rainfall grading from 40 inches in the north to over 100 inches in the southern part of the chicle forests. Archaeologically, the entire area was one of the last outposts of the highly developed Mayan Empire, with cities containing over 300,000 inhabitants and a total peninsular population of possibly three million people. The Empire was already decadent when the Spaniards entered, for reasons still unknown. Ethnographically, the area today contains only 10,000 inhabitants, chiefly Indian though variously diluted with many other breeds of traveler. Health conditions are not favorable. Dysentery is omnipresent, and malaria incidence in the area has been the heaviest in all of Central America. Old people are not to be seen.

The Forest and the Tree. In Mayan times, it would appear, the entire peninsula was cleared and under agricultural use. The more or less continuous jungle of today is thus a "young" forest, with what in this country would be called an "old-field" background. I personally find it impossible to accede to the opinion that the present forest owes many characteristics to this Mayan abandonment, and that the chicle tree is unusually long-lived, with many individuals dating back to Mayan times, "being at least a thousand years old." In my own opinion the Yucatecan jungle is a mosaic of communities, each representing some degree of development following a hurricane, or more rarely a fire. This jungle today is composed of over 100 kinds of forest tree. The trees are distributed with such irregularity, in terms of small quadrats, acres and square miles, that statisticians interested in describing populations in terms of "random" and "contagious" distributions would benefit by their study. The understory is dense, but not impenetrable, composed mainly of young trees. Trails are necessary for mule travel. Palms are frequent. The major forest canopy is 75 feet tall or less. Lianas are common, but by no means do they ape the Hollywood jungle of Tarzan fame. Above this general canopy rise the two jungle giants, mahogany and sapodilla, distributed sparsely, seldom more than a dozen to an acre.

The sapodilla tree plays a rôle in the forest to a great extent still unknown. In my opinion it gets a start in openings, windthrows and wherever else there is light. If overshadowed while still young, the tree can persist, growing slowly, dying back, becoming covered with epiphytic mosses, perhaps lasting through half a century. When it does reach the upper canopy, it develops to its full height, sometimes over 100 feet, with diameters of three and four feet. I have never seen a large tree that appeared to have died naturally other than by windfall. With those dead from chicle tapping, the spot is taken over by any of a hundred odd species; most rarely is *Achras* one of these species.

Achras Zapota is well known to tropical agriculturists of both hemispheres, not for its latex or its timber, but for its fruit. The tree when planted in the open becomes highly branched and produces very little latex, but provides an abundance of thin-skinned fruits that are highly relished among native populations.

The Latex. Latex occurs in a system of laticiferous vessels in the bark of the tree. The function of latex in the physiology of the tree is not yet satisfactorily understood. It probably serves numerous rôles, acting as a vehicle for transportation, as a storage for excretory materials and as a protective covering on wounds. The latex exists under pres-

sure within the vessels, this pressure varying with the season, the time of day, the general site conditions and the individual tree. Once the latex is artificially drained from the vessels, they remain dry and do not secrete new latex. It is only after five or more years, when new phloem has developed with new latex tubes, that a sufficient quantity of latex is present for retapping.

The chiclero, or latex-gatherer, using a machete (a typical Latin-American cutlass, with a blade over two feet long) tests various trees by whacking at the base until a suitable yielder is found. Then he starts "tapping" the tree by making a diagonal incision into the bark, almost always into the wood! A second diagonal is started about 12 inches from the bottom of the first and at right angles to it; then a third such diagonal. Next he climbs the tree, using rope and spurs, making a series of such incisions up to the first branches. The diagonals extend around the trunk, sometimes meeting in back, thus ringing and kill-

FIG. 4. (*Left*). A chiclero tapping a sapodilla tree. Note the chicle bag near the base of the tree, into which the latex trickling from one groove to another collects. (*Courtesy of Wm. Wrigley, Jr. Co.*)

FIG. 5. (*Right*). A chiclero tapping a sapodilla tree. Note the scars of the first tapping on the upper part of the trunk. The incisions are made by means of a machete. (*Courtesy of Wm. Wrigley, Jr. Co.*)

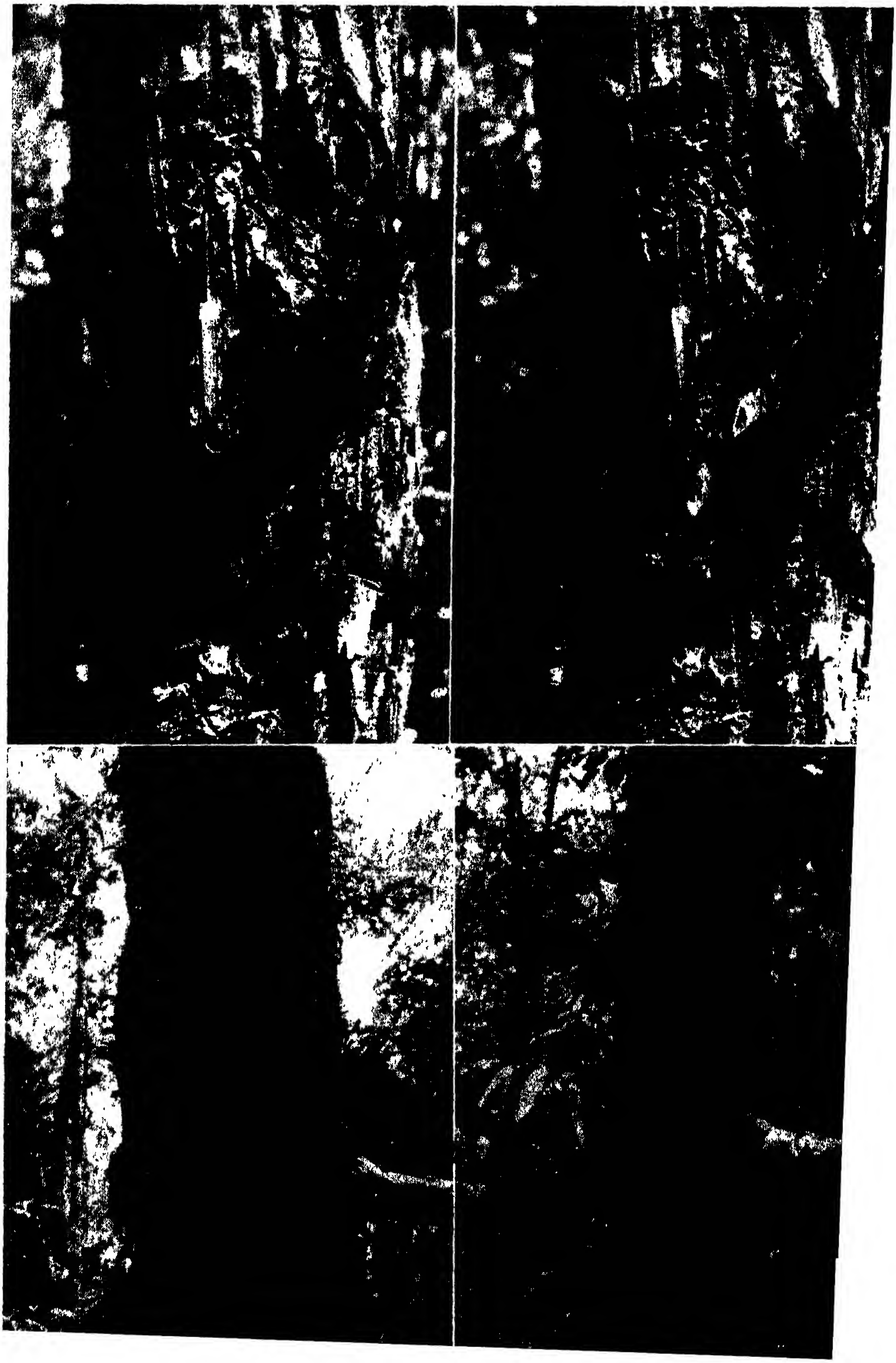
ing the tree. In any event, the injury is serious. Triangles of bark die back; often entire panels between diagonals die. The average tapping-age of a tree is 2.5 tappings or less, with tappings at least five years apart.

On cutting, the latex runs down the central zigzag line. This latex is a smooth milky-white liquid without noticeable inclusions or foreign bodies. It is of varying consistency, depending upon the season, usually thin enough to run freely. When some is placed on the palm of the hand, it can be rubbed up into a small ball, through absorption of the moisture into the hand. This balling is often of value for testing the suitability for chicle of unknown latices. A certain amount of the latex remains in the cut, where it dries and stiffens, and from which it can be peeled off in narrow white strips. Such congealed latex is a tasteless masticatory and was undoubtedly used as such by the original Indians, although there is no indication that such chewing ever became the slavish habit that has since fixed itself upon the more advanced civilizations.

In present tapping procedures, the latex is collected in a rubber bag on the ground at the bottom. Each tree yields from one to two pounds of liquid latex. These bags are collected later in the day and brought to the main camp. They are then emptied into large kettles, sometimes mixed with certain amounts of water, placed over a slow fire and constantly stirred. When the coagulation and cooking has sufficiently thickened the latex, it is poured into wooden molds and allowed to cool and harden. The remaining moisture content is an important factor in the price received for these chicle blocks. The blocks are wrapped in canvas and then await transportation.

In days of mule travel chicle was brought in the dry season over long and winding trails which would take two weeks for distances now covered in one-half hour by air. Two decades ago a road was opened west from the British Honduras border and used by Mack trucks. This temperate-region technique, however, was very expensive, usable for only six weeks out of the year, and was soon abandoned. In Mexico a kind of railroad was used at one place. The airplane, however, solved problems with relatively small initial expense. Today, airfields are scattered over much of the peninsula, putting practically all the chicle areas within one mule-day of a plane. Plane service today is very efficient. In 1942, however, the author wobbled over part of Campeche in an open-cockpit plane with a passenger cabin limited to four by the American manufacturer. Said cabin, however, with seats removed, contained a complete layer of sacks of corn, plus eight men, plus sundry fowls nestled in the interstices. Today almost all chicle is flown to the ports, of which Puerto Barrios serves for Guatemala. From the ports the chicle is shipped to the States for manufacture.

In the manufactories, the chicle is first dried, then melted and centrifuged before further use. This centrifuging frees the chicle from bark, leaves, stems, sand and other extraneous material with which it might have become contaminated. A base, or insoluble cud, of chewing-gum is then formed from 0–40% of true chicle, with the balance composed of jelutong, sorva, pendare, perillo, massaranduba, as well as various synthetic resins and elastomers. The insoluble centrifuged base is combined with powdered sugar, corn syrup and flavor, in 100–200-gallon double-bladed mixers, and then removed to a kneader. The kneader extrudes a thick sheet of gum into a train of reducing rolls called a "sheeting machine". After sheeting to requisite thickness, the chewing-gum is next put through scoring rolls which



mark the sheet into the regular sized sticks. At the wrapping machine the scored sheets are broken into single sticks which are wrapped in the machine at the rate of 160 five-stick packages a minute. These are then boxed and cased for shipment. The finished chewing-gum contains about 20% by weight of the insoluble base, 60% of sugar, 19% of corn syrup, and 1% of flavor.

The Chiclero. The chicle-gatherer, or chiclero, is the most colorful figure in the chicle industry. This individual is drawn either from the scattered Indian settlements in the interior, or from the coastal cities. His employment is seasonal, lasting only through the rainy June-February period. During this time he makes more money than he otherwise would all year. Like any other human being, the chiclero spends freely and liberally while off work, and is only too glad when the next rainy season comes around.

In many cases the chicleros and their families now stay at permanent settlements in the interior, living casually through the dry season. Carmelita is such a settlement, having developed almost entirely since construction of the airport there. These settlements are collections of "bush huts", dwellings with pole sides so widely spaced that windows are quite unnecessary, dirt floors, and thatched roofs of palm leaves that are geometrically attractive from the inside. Kitchens are usually in a lean-to, or a separate structure, and cooking is done over an open fire on a table packed with earth. Latrines are unknown. What would be their contents serve immediately as food for chickens, pigs and dogs, thus completing the food cycle far more directly than with the Chinese farmer who fills a latrine to fertilize his garden, to grow his crops, to feed his chickens, to feed himself. The water supply is not up to modern standards. It is generally a water hole at the center of a large shallow depression in the regional heavy clay soil. At one settlement, the water hole had been fenced in, perhaps originally for purposes of sanitation. Actually, cattle were enclosed within to utilize the lush grass, and a trail beside the enclosing fence served as a town-latrine, nighthawk-nest style. The trail, however, was always cleaned once a year during the rainy season, by surface wash towards the water hole. Lest these ideas of sanitation sound extravagant, it may be said that the author has seen numerous comparable instances in the tropics of both hemispheres, and that 50 years ago, some of the best private homes in crowded downtown New York were only in the latrine stage, for which the backyard chiefly served. In recognition of these unsanitary conditions, I am told that during the manufacturing processes the gums are washed thoroughly, and sterilized at high temperatures with a resulting bacterial count well within legal requirements.

During the chicle collecting season, the chicleros live in temporary settlements in the jungle, under conditions relatively more crude. Rains are frequent, though not incessant; atmospheric humidity extremely high; mud is everywhere, indoors and out; fungous skin diseases are rampant; and water holes are sullied by the mules.

Mule feed in the chicle forests has

Fig. 6. (*Upper left*). Tapping cuts carefully made, apparently without injury but actually resulting in partial death of the underlying cambium.

Fig. 7. (*Upper right*). The bark below the left-hand cut in Fig. 6 has here been removed, revealing a dark area of dead cambium, about 6 x 2 inches.

Fig. 8. (*Lower left*). Trunk showing extensive vertical tapping injury, healed over but enclosing considerable decay.

Fig. 9. (*Lower right*). A twice-tapped tree showing a minimum amount of bark injury.

become a critical problem. Natural grasslands in this area are unknown, and there is no herbaceous undergrowth in the jungle suitable for forage. On air strips and village streets a turf of palatable Bermuda grass (*Cynodon dactylon* (L.) Pers.) may come into existence. Elsewhere "potreros" may be planted of *Panicum* spp., which soon develop into a dense and relatively stable grassland. Frequently, corn has to be flown in to supply the necessary feed. Most commonly, however, while at temporary camps the mules subsist on the foliage of the ramón tree (*Brosimum alicastrum* Swartz). This tree has been reasonably common and is one of the largest jungle trees. The chiclero generally climbs the trunk, lopping off all branches up to several inches in diameter. After such pruning a tree may be reduced to something resembling a telegraph pole, perhaps with one or two stubby branches. The tree apparently sends out new shoots which will again be lopped on attaining suitable size. Basal sprouts are unknown. Dead ramóns in the vicinity of camps, however, indicate that the treatment is too drastic for indefinite survival. Smaller trees up to six inches in diameter are generally chopped down entire, with blissful disregard for the future supply. At the present time the supply of ramón feed is drastically reduced, even though it would be a relatively simple matter of cooperation to develop an orchard of pollarded trees that would produce a suitable crop each year.

The diet of the chiclero is extremely restricted, and probably this situation accounts for much of his poor health. Tortillas (corn-flour pancakes), coffee, and red beans are his staples, eaten three times a day. Rice and wheat-flour biscuits are often cooked. He is generally strongly averse to all other fruits and vegetables. Mangos, bananas, papayas, coconuts, breadfruit and garden crops are relatively unknown. Canned meat is a delicacy, although wild forest game (parrot, boar, pheasant) is liked, as well as the occasional home-fed chicken and pig. While in the forest, game not immediately eaten is often temporarily preserved by barbecuing. In this process the animal is prepared, impaled and suspended over a slow fire where cooking and drying extend over several days. In due time the carcass acquires the hue, consistency and tenderness of an Egyptian mummy, and may be kept thus for varying periods, depending upon the moisture content of the atmosphere.

The chiclero's idea of agriculture at his year-round home is one of the most primitive of the tropics. A section of forest is cut one year and burned the next. A new "milpa" (corn field) may be littered with huge unburned logs, deep holes left from the burning out of stumps, temporarily sterile spots deep in ashes, and lush weed sprouts, all

FIG. 10. (*Upper left*). Narrow-gauge tracks for transportation of chicle latex from La Gloria to San Dimas. The "train" consisted of a mule-pulled flat-car, and served a region of Campeche now largely depleted of chicle.

FIG. 11. (*Upper right*). Tapping injury involving the death of three consecutive panels of cambium and the entrance of decay.

FIG. 12. (*Lower left*). Typical tapping of undersized tree at Campeche. The person is E. A. Sterling. (*Courtesy of James D. Lacy Co.*)

FIG. 13. (*Lower center*). Scars from the first tapping of a typical sapodilla tree. Various cuts near the base indicate where chicleros had previously tested the tree. (*Photo by E. A. Sterling, courtesy of James D. Lacy Co.*)

FIG. 14. (*Lower right*). White latex flowing down the zig-zag incisions of a freshly tapped tree. The long object inserted in the bark for comparison is the three-foot blade of a machete used to make the incisions.

creating such a scene of confusion that one may be excused for not immediately recognizing the site as crop land. Corn is planted in holes poked into the ground with a stick. When the weeds become too dense they are cut with a machete. By the second or third season the new jungle is huskier than the chiclero, and the area is abandoned on the rationalization that the soil is "worn out". Plows are unknown, either man-drawn or mule-drawn. On several occasions I have heard reputable North Americans claim that plows have been sent in, uselessly, as the local mules do not know how to, and will not, draw a plow. These interesting comments—if proven—might be evidence for the inheritance of acquired characteristics in our North American animals, or at least for the superior intelligence of one breed or the other, depending on one's point of view.

The Administrative Organization. In organization the chicle industry is a Topsy-grown creature, easy to criticize but difficult to improve. Governments, landowners, companies, contractors, subcontractors and chicleros all come in for their own independent pound of flesh, with the result that a pound of chicle becomes really high priced. With these several egocentric interests, the welfare of the chicle tree comes last, if at all. Perhaps we should not object too quickly to this short-sighted attitude toward the goose that is laying the golden egg. The chicle industry, under its present administrative organization, is one in which it is openly a matter of you yourself murdering that goose; for if you do not, someone else will.

The sapodilla forest is partitioned among three countries, Guatemala, Mexico and British Honduras. In Guatemala the lands are all in the public domain, and large territorial concessions have been made to the two American companies within which each can direct operations. This situation is changing rapidly. In May, 1946, the Guatemaltecan government sponsored the first chicle coooperative, and in June, 1946, the government authorized the formation of an independent local company, to operate on the same basis as the American concerns. In Mexico some of the land is public, and some is held by large land-owning estates. In British Honduras most of the chicle land is locally owned by private interests, some is held as colonial forests. In all three countries various regulations and rules have been passed which are thought to insure the future of the industry. Such regulations concern the minimum size of tree for tapping, period between tappings, restrictions on tapping of limbs, limitations on total quantity taken from a certain area, and provisions for several-year rest-periods for the tracts. Because of the problem of supervision in most cases, these regulations can seldom be enforced, except on small privately held areas, and even then it is often difficult.

The various American companies are only buyers of chicle. A major part of the industry is divided between the Wrigley interests, on the one hand, and American Chicle (makers of Chiclets) and Beech-Nut Packing Co., on the other hand. These last two have operated jointly in Central America as the Chicle Development Company. Various small independent companies make up the balance. All the companies purchase directly from the owners of the private Mexican estates, or they negotiate with the "contractors" who agree to operate in the territory of the company's concession and to turn over the chicle to company representatives at some jungle base. The companies have financed the airports as part of their transportation system and have arranged various inspection techniques to catch adulterants, inferior chicles, excessive water content and, in older days weight-increasing

stone content. Although it is to the company's advantage to maintain the forest in a productive state, they have no assurance that the concession will continue to be granted to them or that the same contractors will sell to them another year, or will employ the same chicleros.

The contractors are local citizens, sometimes risen from the ranks of the chicleros themselves. Each year the contractor hires a group of chicleros, advances them a certain amount of money with which to buy equipment and supplies, and often provides them with certain materials. Contractors may be allotted a certain area within a company's concession, or they may go out until they find a likely territory and "stake their claims" for the season. Contractors often sell for years to the same company, but they are under no obligation to do so, and it is to their advantage always to sell to the highest bidder. In turn, the contractor can not afford to think of the future of the forest, for if he himself does not kill that goose, there are a dozen others that are ready to do so.

When we consider the chiclero, we realize how impossible it is to regulate the industry for the good of the forest. The trees are scattered 2–12 to an acre. The chiclero goes out one time locating trees. Then he goes out to tap them. He map be able to tap about eight trees a day, but he so works only 15-18 days a month. The remainder of the time is spent in locating the trees, in idleness due to excessive rains, or in cooking the chicle. Thus, in a season of seven months, a chiclero works, on an average, only 126 days. He is paid per pound of chicle. There are other chicleros from the same camp just as eager as he to get the pounds. There are chicleros from all neighbouring camps, also as eager. And next year he may be placed far away in some other area, never to return to this place. With the trees so widely spaced, supervision is impossible. Consequently, no one will know just which tapped trees are his own work. His response is that of any intelligent human being. He gets as much latex as possible in the quickest possible time, with the least expense of energy, from any size tree, regardless of damage to the tree and the future supply. Any conservation measure that cuts down his own production only means more latex for some nearby less ethical chiclero—and there always is such a one. This is no criticism of the chiclero, but of the system which does not, or can not, or will not, give the chiclero sufficient protection so that he can "afford" to practice conservation.

In conclusion, the fact that the industry is spread so thinly over such a large territory permits all sorts of evasions of whatever regulations may be passed. Individual chicleros carry on a certain traffic in chicle between themselves, unknown to the contractor. This is advantageous to the chiclero if he obtains more chicle than agreed upon, either from underlimit trees or from adjacent tracts. Large private properties are difficult to patrol, even if the boundaries have been opened, and it is always to the advantage of the contractor to get chicle in the easiest most convenient manner. Consequently, production figures from the different estates are not always reliable. Furthermore, the unpatrolled international boundaries offer even greater inducements for evading regulations. For example, a small section of one country has been fairly well depleted of chicle by gatherers from the adjacent country. Furthermore, at some trail-crossings, international borders have none of the expressions of authority we usually associate with them. Even nearby settlements often have no evidence of civil authority. It is said that certain ones have crossed

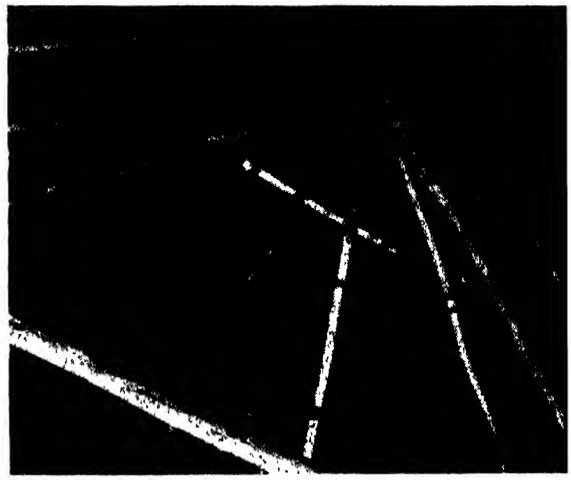



FIG. 15. (*Upper left*). A typical open-fire cooking table in northern British Honduras. The fire is built directly on the marl-packed table, and the grill is made from scrap metal.

FIG. 16. (*Upper right*). The interior of a typical bush-hut in northern British Honduras. Note the lianas used for tying the structure together, and the neatly arranged rows of palm thatch.

FIG. 17. (*Lower left*). The town of La Gloria, Campeche, with the terminus of the San Dimas ''railroad'' at the left foreground. Deep mud marked the central ''plaza'', though the picture was taken in the dry season.

FIG. 18. (*Lower right*). The author's bush-hut headquarters in northern British Honduras. Only vines and lianas are used to hold the structure together. Sleeping hut at left; kitchen hut at right.

and recrossed such borders, and stayed in a country for varying periods, without benefit of formalities, visas and permits, neglect of which in normal situations has produced interesting effects. For all these reasons, production figures from the countries themselves are often unreliable and may give misleading indications of the state of the industry.

Some Current Trends in American Industrial Research

Before proceeding to a discussion of chicle research it will be well to scan the general field of American industrial research. Chicle investigations are a small though significant element of this total American scene, and can not be interpreted properly without reference

to the whole. Furthermore, it may be assumed that more and more will the chicle research of the future be influenced by the entire industrial picture in this country. The current and rapidly changing status of three aspects of this subject are considered in the following paragraphs which deal respectively with research in general, American research and American industrial research.

We live now in a day of complete reorientation toward research. There used to be an unbridgeable gap between "applied research" and "pure research". Applied research was once carried out in more or less of a trial-and-error method, without organization and continuity. Pure research was an out-and-out luxury, to be indulged in by that socially useless minority who had sufficient means to putter in an ivory tower. Society throughout the world did not object to such activity, neither did it encourage it. Perhaps history will recognize August, 1945, as the turning point in civilization's attitude toward that pure research. In a few awful seconds the entire world was allowed to learn that the intellectual putterings of several generations of those "pure scientists" had become the most potent mass of practical knowledge that any government, or people, or group ever possessed. Almost overnight the new "basic research" caught on and is today supported in many countries in a manner undreamed of by the pure scientist of other years. I do not at all intend to imply that the pure scientist has now become an applied scientist, working for immediate and recognizable technologic goals. To the contrary, the psychology of the pure researcher remains unchanged; it is only that the practical man, gaining by hindsight, has increased his foresight, and is now openly exploiting the products of that ivory tower. As such he looks upon the matter as a very profitable undertaking. This new combine of personnel is entirely logical. "I suppose that the reason digging for truth is not only more interesting, but more profitable, than digging for gold is that if urged on by the love of digging, one digs more deeply than if searching for some particular nugget. Practicality is likely to be shortsighted and looks so hard for some single objective that it may miss much that nature presents to one who is purposely digging for whatever may turn up"[2]. The import of all these current research trends to the chicle industry is both interesting and instructive.

American research had progressed significantly though slowly, before 1940. In 1930 the nation spent $166.1 millions for all research, including industry, government and university. In 1936 the figure had risen to $218.1; in 1940 to $345.2, of which $69.1 was government research. In 1942 government research alone had become $332.1, and in 1944 it was up to $719.8 millions. The combined research and development program of the federal government is today as large as, and in certain instances larger than, during the war. Current expenditures are at about 20 times the 1940 level, and for the first half of 1947 they will be at the rate of $1,500 millions, exclusive of the Manhattan project. On the other hand, the rôle of fundamental studies in the early history is not so creditable. In several respects, American science can take little pride in its past performance of basic research. Even though we have been preeminent in the application of fundamental knowledge to practical problems, a large proportion of the original discoveries have been made abroad. If the awarding of Nobel prizes is an indication of active basic research, it should be significant that we have received only one out of seven such awards in the fields of physics, chemistry, medicine and physi-

[2] Harrison, G. R. Science 103: 125. 1946.






FIGS. 19, 20, 21. (*Upper row & Center left*). The main street in Carmelita, Peten, a typical native village of the Yucatan Peninsula.

FIG. 22. (*Center right*). Interior of a Douglas DC2 used for transporting chicle out of the jungle. Each bag contains about 150 pounds in irregular blocks of gum, and the usual flying load is 5,000 pounds.

FIG. 23. (*Lower left*). Airplane field at Villa Hermosa, March, 1946, showing the antiquated single-motor plane used for transporting chicle 150 miles to the coast.

FIG. 24. (*Lower right*). Loading chicle at Carmelita. (*Photos 19–24 by E. A. Sterling, courtesy of James D. Lacy Co.*)

ology. Although figures for national basic research are not available, we can observe trends from other sources. American university research, constituting the main stronghold for basic studies, cost only $20.3 millions in 1930, $25.0 in 1936, and $31.4 in 1940. In 1945 both houses of Congress argued the

pros and cons of a National Science Foundation, one important function of which was to encourage such basic research. This Foundation was estimated to cost $33.5 millions in its first year, and $122.5 when it reached stability in its fifth year. While Congress disputed the details of the Foundation, the Army and Navy embarked on their own programs, believing in the necessity of immediately supporting such fundamental studies. In 1945 alone the Army and Navy expended about $140 millions for basic research in universities and laboratories. For the Navy this involved some 90 contracts, covering 235 projects, 70 per cent of which are with universities. Government sponsoring of basic independent research is by no means limited to the military. As one of several possible examples, the U. S. Public Health Service Research Grants now total $3.9 millions for a period of less than a year. They involve 264 research projects in 77 institutions, and are granted to independent scientists, with remarkable freedom from control and regulation. It would be assumed that these changing forces would be reflected by parallel trends in the chicle industry.

The history of American industrial research also shows an interesting accelerating curve. Research expenditures by industry in 1920 were only $29.4 millions; in 1930 $116.0; in 1936 $152.0, and in 1940 $234.0 millions. There are now said to be 2,264 industrial research laboratories in this country, although many of them are probably only developmental and trouble-shooting offices. On the other hand, both pineapple and sugar industries in Hawaii have for years sponsored cooperative experiment stations on a lavish scale. The industry-sponsored Sugar Foundation in North America has an exceptionally large research program. We find more and more corporations establishing the position of Director of Research. This person now is frequently an integral executive with the title of Vice-President in Charge of Research, to wit, C. E. Kenneth Mees of Eastman Kodak Co., and the nationally known C. F. Kettering of General Motors Corporation, recently President of the American Association for the Advancement of Science. Several years ago Dr. Compton told the National Association of Manufacturers that two per cent of the gross income of any industry could be expended effectively on research, a figure which might be applied with interest to actual current research expenses of the chicle industry. It is true that "industrial research traditionally has consisted primarily of developing and perfecting the application of fundamental discoveries made in the non-commercial laboratories. . . . If the universities [however] are not enabled to carry on their fundamental researches at a pace commensurate with the need, then industry, as a matter of self-protection, will have to devote increasing attention to this type of research problem. . . . Before this type of investigation can be pursued by industry to an adequate degree, management will have to be convinced of the necessity of such studies. The directors of research will have to demonstrate to Boards of Directors that money spent in such research is as productive in the long run as is applied research designed for immediate commercial application"[3].

Today we find numerous expressions that such fundamental research is now becoming a profitable undertaking for some of the larger corporations. For example, the Escuela Agrícola Panamericana in Honduras is supported entirely by the United Fruit Co. This agricultural school is for training young men in all fields of tropical agriculture, and for research in a variety of tropical food plants. Corporations like Bell Telephone, General Motors and General

[3] Tainter, M. L. Science 103: 95. 1946.

Electric are sponsoring fundamental research with a thoroughness never before expressed. Coupled with the realization that the functioning of basic research must depend on properly trained personnel, industry has stepped into the field of assisting in that training. For example, Merck & Co. has recently announced (Nov., 1946) an appropriation of $100,000 to support a series of post-doctorate fellowships with unusual latitude in choice of the field of research and with freedom of publication of results, coupled with opportunity for advanced courses of study. The new "Industrial Research Laboratories of the United States" lists 302 companies which are providing fellowships, scholarships or grants of research, to all of which are accorded a large degree of freedom. These funds are distributed in some 1,800 grants, representing an expenditure of probably more than $10 million per year. This large sum is about half that which was spent for all research in all universities in this country in 1930! With this handwriting on the wall, it appears as though American industry has committed itself, not only to a sizable program of applied research for immediate benefit, but also to a far-sighted long-range policy of basic research. The influences of this national trend on the chicle industry will undoubtedly be of great interest.

Past Chicle Research

It is often useful to consider research as being carried out by three agencies: private organizations, government, and industry. The investigations by private organizations, such as research institutes and universities, are not readily separable from numerous fundamental researches in allied laticiferous plants, including rubber and its substitutes. Various students of J. S. Karling have worked on latex and latex vessels of plants other than *Achras* since 1926. Independent research on *Achras* itself, however, is more limited. Several large landholding estates in Mexico have issued reports based on sampling techniques, as a basis for their exploitation programs. It is well to mention here that T. H. Everett, Horticulturist at the New York Botanical Garden, has succeeded in rooting *Achras* cuttings by air-layering. Such rooting, hitherto unreported, may be one of the most important single factors in establishing plantation trees in the dense and rapidly growing tropical undergrowth. In a different category entirely are the precise psychological studies, such as that of Hollingworth on the relationships between chewing and metabolism, strain and work efficiency. These studies provide evidence that chewing reduces tension, reduces the energy that otherwise is wasted in various random movements, that the chewing itself absorbs only a small amount of this saved energy, and that some of it is actually discharged into the main occupation. What impressive advertising slogans may lie in studies of this kind that may be carried out in the future!

In respect to the second agency, governments, I am not aware that either Guatemala or Mexico has carried on any investigations other than possibly certain surveys and inventories leading to the more or less arbitrary establishment of rules and regulations supposedly conserving the supply of chicle. In British Honduras the colonial government has exhibited a more far-reaching policy and has not only cooperated with industry but has carried out certain researches of its own. In the main these have concerned techniques of tapping and have been based at the Freshwater Creek Forest Preserve in the northern part of the colony. To my knowledge the researches have not yet yielded significantly valuable results.

Thirdly, in industry-sponsored chicle

research we come to an interesting and instructive phase. In the first place we must distinguish between botanical research on chicle-yielding plants and chemistry research on synthetic substitutes. Synthetics research remains largely intra-company information and is beyond the scope of this article. During the last War a popular chewing gum is said to have been at least three-quarters synthetic, and though it has now been removed from the market as inferior, the possibilities of a suitable synthetic are very real. Although at this time such possibilities must have repercussions on the interest in botanical research, this was certainly not true in previous years.

Industry-sponsored botanical research can bear division into two groups, based, respectively, on the two leading companies in the industry. One of these took the stand a quarter of a century ago—and with considerable justification—that experiment station research is not practical for chicle. Other than a limited amount of area-cruising, that company has entered on no botanical investigations within its research division. The other company has engaged in research; it has followed a liberal policy of publicizing the results of this research, believing that it is to the benefit of the entire industry to do so. It is on the basis of such public records that the following statements are made.

The entire significant history of chicle research, despite its violent fluctuations, is encompassed in a mere quarter of a century. In 1921 Mr. Hummel, then Forestry Officer of British Honduras, published his "Report on the Forests of British Honduras, with Suggestions for a Far Reaching Forest Policy". This policy recommended a conversion of the native jungle to a sapodilla plantation. The results of the passage of time indicate that Mr. Hummel is more to be commended for his high-pressure salesmanship than for the professional worth of these unique silvicultural theories. He sold his idea not only to the industry officials, but to the entire colonial Forest Office—though not to other interests. A forty-thousand acre tract was privately purchased in 1924, and operations were begun in full intensity and with the hearty cooperation of government. Brief reports on these forestry operations appeared in the Annual Reports of the British Honduras Forest Trust through the year 1928. By that time, however, it became apparent that expected results were not being obtained. Thus this unfortunate project—questionably to be designated as "research"—was completely abandoned. To my knowledge, the negative results were not reported and evaluated as a technical project, and the conclusion was psychologically fixated that sapodilla was not, and would never be, suitable for plantation development.

The next investigation venture was more successful in scientific worth, if not in immediately applicable results. Dr. J. S. Karling of Columbia University, working for industry through the Tropical Plant Research Foundation, and on the same 40,000 acre tract, carried through a five-year (1927–1932) series of tapping investigations, all important results of which appeared in several articles by Karling and by Lundell. At Dr. Karling's suggestion that the tapping studies be discontinued, it appears that not only they but the entire investigative structure in British Honduras collapsed, apparently with the abandonment, loss or misplacement of various materials and records.

It was almost a decade later that the future of the industry again began to weigh heavily on certain minds. The author was borrowed from his university for intensive field surveys in Central America, and on the basis of his recommendations, an Experiment Station was

established. This station was not only to embark on an active research program on termination of the War, but was to serve as an administrative research unit within the industry, to ride through expected waves of interest and disinterest, and to serve as a continuous medium for preserving the records, files and information of importance to research. The short life of the Station is reflected in three mimeographed reports, copies of which are in the British Honduras forest office, and in three published articles by the author. The author resigned as Director in October, 1944. No successor has been appointed, and assumedly the Station has lapsed into non-existence. Once again a stasis was obtained.

Connecting and anastomosing among the threads of these three chapters are a series of short-time projects, often creditable, sometimes carried to completion, sometimes abandoned as soon as results began to appear negative. These projects have been carried out on a retained consultant basis or on short-term assignments. In this category are to be placed various surveys and investigations by the James D. Lacey Co., to ascertain the amount of exploitable chicle in the forests, a popular report of which was published by Sterling. In addition, there are sundry taxonomic investigations that have appeared by Cronquist, Gilly and Monachino. Even in its taxonomic work—one of its few ventures into basic research—the industry has not always obtained results that encourage it in this line. For example, Gilly has found good and valid cause to abandon the fine old name of *Achras Zapota*. In addition, however, this old familiar sapodilla was disrupted into ten species, plus varieties. These segregates were recognizable only by flower characters—a pesky situation for the field man, for the tree is usually flowerless in nature and in the herbarium. Scarcely had the significance of this complexity begun to be absorbed when Cronquist, approaching the problem from other and more conservative standards, reduced the ten species to three. Verily, when the gods themselves dispute, whom is the common man to follow?

Within recent months, there have been numerous changes in the policies of the companies regarding research. Reports are conflicting and often contradictory. In general, it appears that research on *Achras* is completely halted, but that an investigative program on other natural gums, especially jelutong, has been and is in process of formation.

As we glance backward we see that the lavish and unlimited exploitation of natural resources has started to raise some wrinkles on the brows of the more far-sighted. Continued opening of virgin areas, however, has caused others to take such fears and worries quite lightly. The real nature of scientific research and careful preliminary application of research results are not in my opinion yet segregated from strip surveys for estimating existing quantities of chicle. Nor are they segregated from the desire for a plunging all-out offensive, à la Hummel, such as would put the industry on a permanent basis, overnight, or at least as quickly as man-hours could be applied. The actual research, if one desires to call it that, has too often been encompassed in such a phrase as "How much chicle can be taken out of a given area without jeopardizing future production?" This question will always stymie field botanists who know the Yucatecan jungle, for it implies a fundamental misconception of the entire situation. The poor botanist may feel himself confronted with a psychologic problem in adult education, rather than with the accumu-

lation of new botanic data. At times, the not undangerous policy may have been followed of hiring men of various professional categories to agree with previously decided opinions, and to work on specific short-time objectives, sometimes for specific pre-determined results. In such instances, when results begin to appear negative, or even before, interest may be lost, the work stopped, often the records may be lost. Such a policy favors sterile repetition, with regularly repeated still sterile failures, coupled with unwarranted negative conclusions. In summary, we can say that "basic research", in the sense that we have used the phrase in this paper, is still undeveloped, as evidenced by existing publications. What work has been done in this category, as by Karling, can largely be placed at the hands of basic-research minded botanists who have effected them despite, rather than because of, the encouragement of industry.

This retrospect over the past quarter century by no means warrants criticism or adverse comment. It is presented here as a record and interpretation of historical fact. It represents an extremely interesting and normal period of an industry which is based on the exploitation of a natural resource. It bears curious and instructive parallels to such developments as have already been experienced by the rubber industry, by timber forestry, by the cattle-range industry and many others, all now well buttressed by stable research programs. It appears to me a perfectly normal chapter, analogous to what in other industries has been a normal growth. The final story—one facet among many in the history of American industrial research—remains for the future to unfold.

Potential Chicle Research

With the conspectus that has been presented, the phytologist can indeed wax enthusiastic about the research future of the chicle industry. Evolutionary trends can not be thwarted, even in the field of human economics, and it is only natural to expect that the chicle industry will some day enter another stage, following in the footsteps of rubber, sugar, pineapple, citrus fruits, bananas, hemp and many others. Even the development of a synthetic substitute need occasion no great pessimism, if we are to be influenced by the still great importance of natural rubber beside its synthetic substitutes.

To merely list the possible fields of research on chicle trees would be beyond the scope of this paper. It is easier to state that as a research subject, the field is essentially virgin. What we do not know is astounding. We do not have sufficient data by which to gauge height and diameter growth rates, the age of tappable trees, the age at which tapping is first possible, or the ecologic requirements for maximum growth. We know almost nothing of the forest itself, and of the rôle of the sapodilla in it. To assume that a plantation industry is impossible is as premature as to have assumed the same thing for rubber at a comparable stage in rubber history. And finally, numerous other species around the world give usable latex. We know even less about these plants than we do about sapodilla. What specific facts and techniques will eventually be extracted from the mass of future research-acquired data, to mold the industry of tomorrow, no one now knows. We who sit on the side lines can look forward to an unfolding and eventful panorama in the long history of man's utilization of the world's plants.

Plantation Rubber in the New World

The exigencies of the recent war induced the establishment of rubber plantations in the New World, of which there may now be 30,000 acres in the Island of Haiti, Mexico, Central America and northern South America.

W. N. BANGHAM[1]

Plant Sources of Commercial Rubber

ALTHOUGH rubber is elaborated, to some extent at least, by about 1,500 species of plants, few of these species form a sufficient quantity or a satisfactory quality of it to have achieved value as commercial rubber producers. In general, the rubber that is present within the specialized cells or latex systems of most of those species is so intermixed with resins, gums or other materials as to render extraction of it in reasonably pure form very difficult. Of the plants from which rubber can be obtained by destroying and disintegrating the plant source itself, only guayule (*Parthenium argentatum* A. Gray), a shrub native to the arid areas of the southwestern United States and northern Mexico, has attained importance. Among those which yield a rubber-containing latex and which therefore need not be destroyed and disintegrated, are a few trees and vines native to Africa and southern Asia (*Funtumia elastica* (Preuss.) Stapf., *Landolphia* sps., *Cryptostegia* sps. and *Ficus elastica* Roxb., chiefly). They attained some importance when rubber was available only from native jungle sources or when the flow of it was diminished by restrictions on commerce, by war or by governmental decree. None of them, however, has been a satisfactory plantation source of the material.

In the earliest contacts that European visitors had with the natives of the Americas they found rubber used in balls and as a waterproofing cover for cloth. Much of this rubber is supposed to have come from *Castilla elastica* Cerv. trees which were native to the regions first visited. This species has been planted in plantations at various times since then but has not given satisfactory sustained production. *Manihot Glaziovii* Müll.-Arg., a tree native to dry regions in Brazil, was also planted in a few early tests, and a considerable commercial planting of improved selections of guayule has been made in the southwestern United States. All these sources, together with wild *Hevea* of the Amazon Valley, accounted for approximately only two per cent of the total world rubber production in the years immediately preceding the war. It was the cultivated plantations of *Hevea brasiliensis* Müll.-Arg. which had become, by all odds, the dominant sources contributing to the world rubber production which before the war amounted to 1,500,000 tons each year, with a value of $756,000,000 at the fixed buying price of the United States during 1941.

Tapajos Jungle Provided Planting Stock for Oriental Rubber Plantations Free from Leaf Disease

Unique in the history of major world crops is our information about the origin of the planting material for the approximately 9,000,000 acres which have been

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planted with *Hevea* throughout the tropical regions of the world. This entire area, with a few minor exceptions, was planted with the progeny of one collection of 70,000 seeds, of which only some 2,800 germinated and survived. It is quite possible that some of the trees from which Henry Wickham (later to become Sir Henry Wickham, in recognition of his contribution to Empire Agriculture) collected these seeds in 1876 still stand on the plateau area 500 feet above the banks of the Tapajos River in Brazil, where he gathered them, and that some may still contribute to the native rubber production of the Amazon basin.

Only the genes which were present in this population from a very restricted location have been available to later breeders who worked on the plantations of Sumatra, Java and Malaya in their attempts to increase yields and to better adapt *Hevea* trees to plantation culture. The *Hevea* trees which grew in scattered distribution on the high banks of the Tapajos River, where there is a long and distinct dry period often accompanied by strong winds at the period of leaf change (wintering), rarely were severely damaged by the principal *Hevea* disease, South American leaf-blight, caused by the fungus *Dothidella ulei*. The population of *Hevea* trees in this area had not then been subject to natural selection strong enough to build into it a satisfactory amount of resistance to this disease to protect the trees when they were planted at plantation density in areas in which the environment was less favorable than that of their native plateau. Fortunately, however, for the industry which later developed from this collection of seeds, Wickham did not carry with him on the seeds viable spores of the blight. If he did include some they were lost during the journey or during the period in which the seedlings were maintained in the greenhouses of Kew Gardens. The seedlings thus did not carry the disease to the plantations which were established with them in Ceylon, Malaya and Java, and drastic control of the export of planting material of *Hevea* subsequently maintained by South American countries prevented transfer of the disease to the major plantation areas of the world with later collections of *Hevea*. The disease, therefore, was not introduced into the Orient, and the plantation areas of the East and the search for planting materials with superior ability to produce high yields was not hampered by the necessity to also develop resistance to this serious leaf blight.

Native Leaf Disease Prevented Use of Hevea on New World Plantations and Induced Attempts with Other Species

The freedom of Oriental plantations from the blight was not duplicated in New World plantings in regions in which *Hevea* was native. Only in limited areas which were favored with unusually fortunate climatic conditions did attempts to establish *Hevea* on plantations in Trinidad, the Guianas or the Amazon Valley result in mature and producing trees. Usually, however, these efforts ended in disaster after the South American leaf-blight successively destroyed all or most of the leaves of each new flush that appeared in the course of a few years.

During periods of high rubber prices a great expenditure of capital of American, European and of local origin was invested in Mexico, Central America and South America to establish rubber plantations. After the risks connected with planting *Hevea* became well publicized, most of the plantations were planted with *Castilla* trees, but production from these trees was low, under the severe tapping practices in current use. The plantations rarely survived long in the hands of the original owners, after the plantations of *Hevea* in Ceylon and

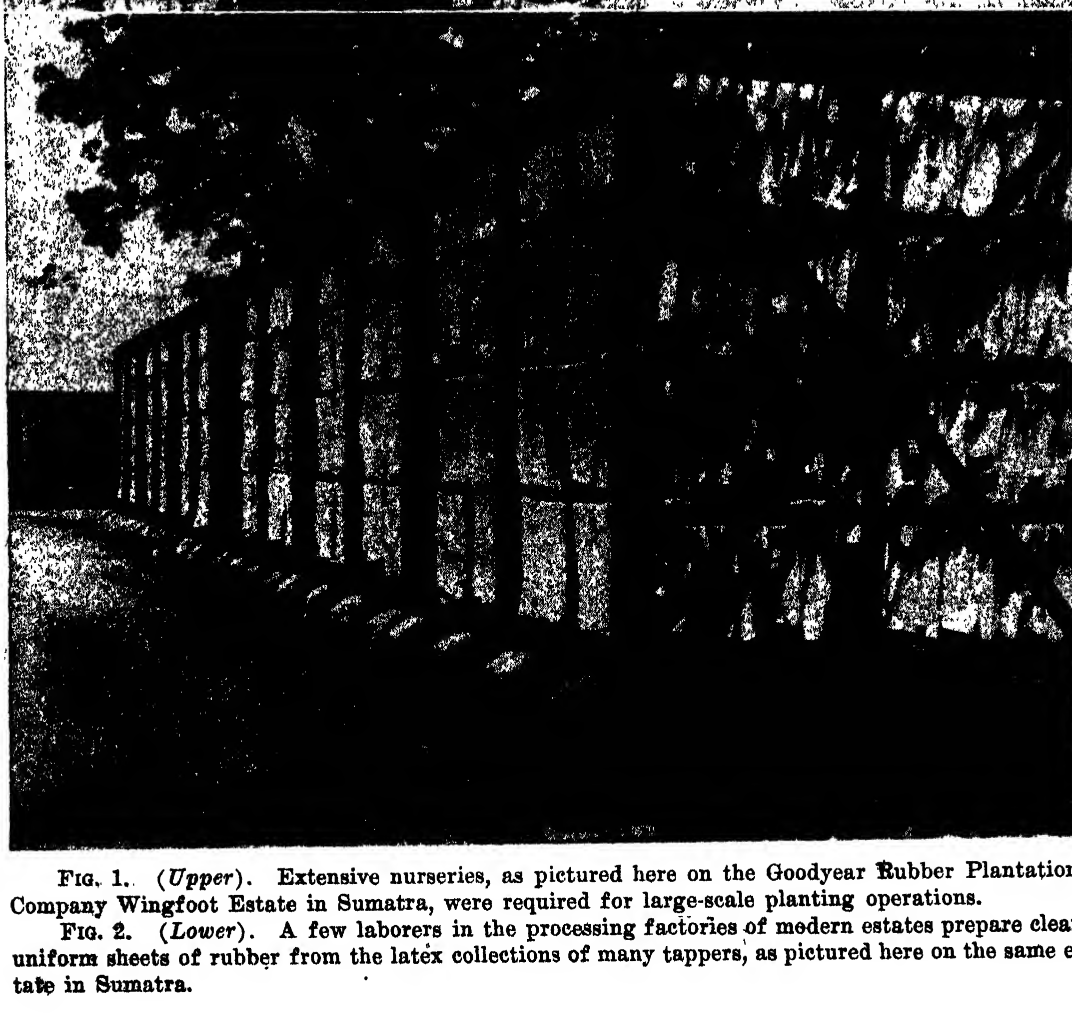


FIG. 1. (*Upper*). Extensive nurseries, as pictured here on the Goodyear Rubber Plantations Company Wingfoot Estate in Sumatra, were required for large-scale planting operations.

FIG. 2. (*Lower*). A few laborers in the processing factories of modern estates prepare clean, uniform sheets of rubber from the latex collections of many tappers, as pictured here on the same estate in Sumatra.

Malaya started production on a large scale. The total loss of investment which the investors suffered in these American plantations gave rubber as a plantation crop in the American tropical areas a permanent shock, from which it has not recovered.

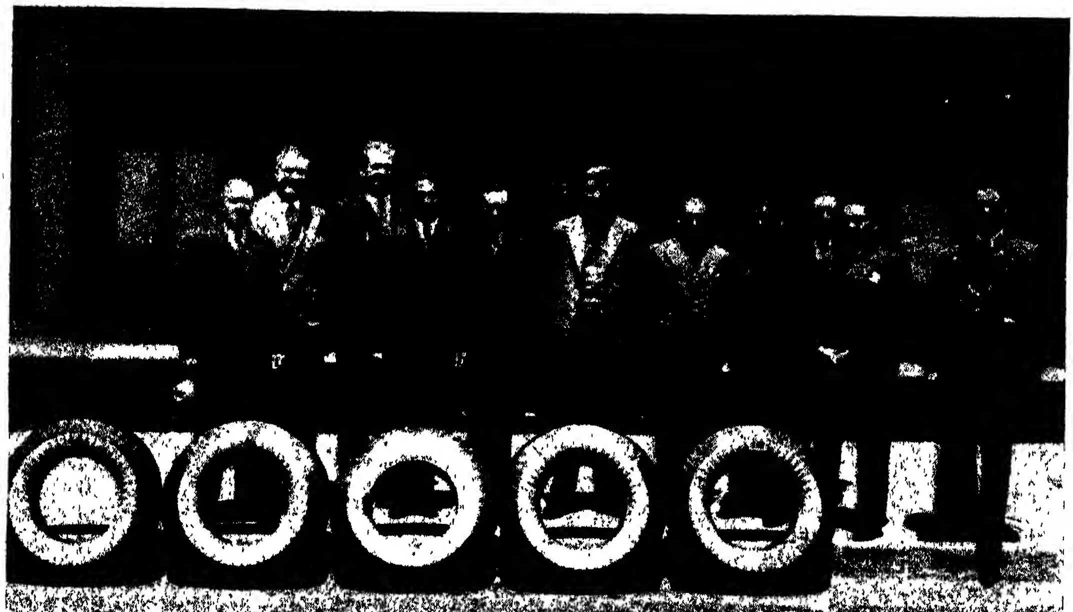
When *Castilla* plantations failed because production costs were high and the quality of the rubber was low in comparison with that of *Hevea*, many of the trees survived among the competitive jungle growth which came up among them. These survivors served as the source of much of the *Castilla* rubber which helped so vitally in the production of war materials during the recent war. Although there does not appear to be any need to consider *Castilla* as a plantation tree in the immediate future, there is justification for some protection of this tree in jungle areas, for its value as an emergency source of rubber.

Guayule rubber was adapted to plantation culture largely through the efforts of Dr. David Spence and his staff in the laboratories of the Inter-Continental Rubber Co. at Salinas, California. This group, which has recently had the help of governmental and University agencies, has improved rubber yields, decreased resin content and developed cultural, harvesting and processing machinery. Even with the remarkable improvements which were made in the plants and the substitution of machines for human labor in handling, the crops have not yet reduced production costs to a point which will permit guayule to compete with improved *Hevea* on a direct cost basis. The rubber from guayule is said to be particularly well adapted to use in certain mixtures with synthetics, and it may find a place permanently in the agriculture of certain arid areas, but it appears improbable that it will in the near future supply a larger percentage of the plantation rubber than it does at this time.

No other species of plant has threatened the dominating position of *Hevea brasiliensis* in rubber production, or appears likely to do so. It is possible that synthetic materials will continue to replace some rubber in tires and other products which utilize large volumes. The extent of this substitution will depend chiefly on the legislation which will determine the national policy with respect to the synthetic factories. Despite the low price at which it was estimated that synthetic could be made with the most modern methods (one estimate was between 13 and 15 cents per pound), the former plantations of improved *Hevea*, with unrestricted export, could operate at a profit in years prior to the war. It is impossible to determine either the potential quantity or cost of rubber which will come from the plantation areas of Indonesia and Malaya after this period of social unrest resolves itself. It is very certain that wages will increase and that labor productivity will be lowered in that area. These changes will lower the differential between the cost of producing rubber in the East and the same costs in the Americas.

Most Eastern Plantations Are Planted with Low-Yielding Hevea

Approximately 90% of the plantation areas of *Hevea* in the Orient, including native-planted areas, are planted with a random mixture of seedling progeny from the original Wickham trees. This type of planting material has produced an annual yield of 450 to 500 pounds of dry rubber per acre per year on large European plantations, and somewhat more than that on the thickly planted native holdings. Mr. H. N. Whitford, of the Rubber Manufacturer's Association, found the native tappers to bring in from their own holdings about eight pounds of dry rubber for each day of tapping, and these men usually used a part of the day to process their product.



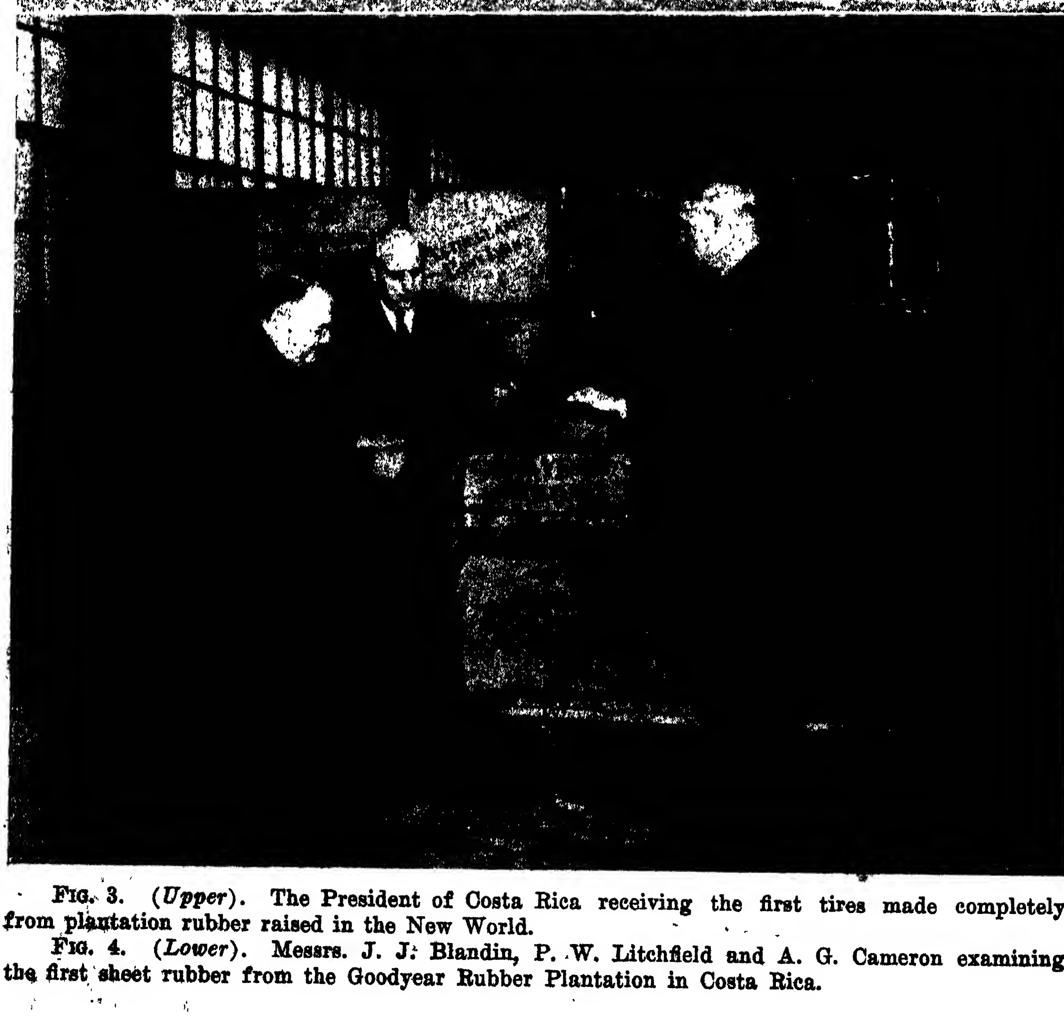


FIG. 3. (*Upper*). The President of Costa Rica receiving the first tires made completely from plantation rubber raised in the New World.

FIG. 4. (*Lower*). Messrs. J. J. Blandin, P. W. Litchfield and A. G. Cameron examining the first sheet rubber from the Goodyear Rubber Plantation in Costa Rica.

Careful control, on the other hand, of tapping procedure and of tapping panel diseases has permitted tappers on European-operated estates to collect from 18 to 20 pounds of dry rubber from each day's tapping, from similar unselected trees. On the estates one man in the factory could process the product of ten or more tappers each day.

The remaining 10% of the plantations in the East, all European or American owned, were planted with trees that originated in an extensive breeding and selection program. Perhaps 20,000,000 seedling trees had their yields recorded for a period of a year or more to select the superior trees. Progenies of these were propagated by budding. Yield tests of the progenies gave an indication of the value of the clones for larger scale trials.

By generative crosses among the best seedlings discovered within the natural stands, production was increased to levels above that of natural populations. The mean yield of a population from the superior parents frequently was equal to that of the parents, indicating that the mean had been increased by selection and one generation of crossing to a level approximately three times the mean of the population from which the parents had been chosen. Few of the combinations or re-combinations involving more than two generations of crossing within this selected body of material had been tapped before research stopped in the Indonesian and Malayan areas with the arrival of Jap invaders. Since improvement was so rapid in these first generations, it appears reasonable to assume that improvement of the *Hevea* tree has not reached the maximum ceiling for yields. We anxiously await information as to the yields of advanced generations, which should be mature when the Indies are re-opened.

In addition to providing an increase in the yield-potential of the trees, the selection program eliminated, when possible, those clones which were unduly susceptible to a breakdown of the latex vessels (brownbast), to severe wind damage and to uneven renewal of bark on the tapped panels, and also eliminated trees with a branching habit which would not stand the competition of planting in stands of mixed clones.

The best of the clones which originated from selections of outstanding trees in natural seedling populations gave commercial yields on a large scale that was about three times that of the population from which it was selected, or about 1,500 pounds per acre per year. The best of the clones resulting from controlled crosses has given 2,000 pounds from large plots. Tappers working in tasks of such trees bring to the collecting station the equivalent of 40 to 60 pounds of rubber per day. With a minimum of 300 tapping days, a tapper working with this class of *Hevea* can get an annual yield of 12,000 pounds of rubber.

Jungle Rubber Gives Meagre Return from Land or Labor

How does this return compare with that of the Indian who hunts his rubber from wild trees? The Rubber Development Corporation has made an extensive check of the annual crop of rubber tappers in South America during the war years, and has reported that the yields vary from a low of 440 pounds in the Iquitos area of Peru to 1,760 pounds in the Rio Beni area of Bolivia. The data on the page following indicate the comparative yields of the various tappers and their annual crop values at the 1941 world price of $0.225.

The relative advantage of the estate laborer is reduced by reason of the capital required to prepare the plantation for him to tap, and by the upkeep and factory labor which assist him in processing rubber from the latex that he collects. When we discount these factors we still

ANNUAL RUBBER CROP PER TAPPER

Tapper	Type of Tree	Yield (pounds dry)			Value ($ USA)
		Per Tree	Per Acre	Per Tapper	
Native Iquitos	Wild	2	—	440	$ 99.00
Native Rio Beni	Wild	?	—	1760	396.00
Sumatra native	Unselected	5	600	2400	540.00
Sumatra estate labor	Unselected	6	450	5400	1215.00
Sumatra estate labor	Best clones	15	1500	12000	2700.00

find that the tapper working with improved clones in an estate has a very marked superiority in his annual crop as compared with the native in the jungle or the native small-holder in Sumatra, who taps relatively low-yielding trees.

It is not necessary for prospective plantations in the Americas to pass through the same stages of economic development as do those of the Indonesian natives, with their available land planted to rubber on a low productive level. High-yielding clones can be planted here, and the American plantations will have the advantage of production levels equivalent of those of the top 10% of the industry in the East. The Inter-American Economic and Social Council of the Pan-American Union reported that 69,185 laborers were occupied in the collection of rubber from wild sources in South America during 1944. Even in times of extremely low prices many of these tappers continue to exploit rubber. Would it not be good economy to aid them to plant improved rubber trees near their homes and to get the advantages of this greatly increased efficiency of labor and land use? We cannot explain the production of rubber by the Amazon natives on the basis of an attractive return, but if they are attached so tenaciously to their localities, it is possible with planted rubber to bring them a more fruitful life in their customary occupation.

Not only do the laborers in the wild rubber areas obtain a small return for their effort, but they are subjected to very unhealthful conditions, a lack of medical facilities and a very high mortality. Poor temporary shacks provide shelter, food is often scarce and poor in quality, and medical services cannot reach remote locations. With a single hectare of the best available clones, top-budded with a resistant clone, the tapper could live and work within sight of his home and still obtain as much as seven times the rubber that he now gets from a year's work.

Concentration of rubber production into small units of planted area will make it possible for the rubber tappers to live in more comfortable permanent houses, where an adequate supply of food and medical services will be possible. Despite the advantages to be gained from having planted rubber replace the wild, the impetus to make this change will not come from the tappers themselves, at least not until they can see in their region producing units on the scale of their potential holdings. If these units are established by a local governmental agency they will encourage the spread of this type of planting.

Production Restrictions Bring Rubber Back Home

Despite earlier failures to establish a rubber plantation industry in the Americas, development of these plantations obtained new impetus from the promulgation of the "Stevenson Scheme" to restrict export of rubber from the chief producing areas within the British Empire. The Ford Motor Company purchased a concession of about 2,500,000 acres along the Tapajos River in Brazil, in which it planned to exploit timber and jungle products and later to plant the deforested area with plantation rubber.

The United Fruit Company imported some seed from selected high-yielding "Mother Trees" from the estates of the United States Rubber Company in Sumatra. This company started small rubber plantations on land in Costa Rica, Honduras and Panama, which had no further utility for growing bananas, after the soil had become infected with Panama Disease (*Fusarium cubense*).

The Ford attempt to exploit the Amazonian timber and other jungle products was ill-timed. Depression economy which dominated world trade at the time they were ready for market did not permit profitable introduction of the new products. Wood-working machinery could not cope with many of the extremely hard woods, kiln-drying procedures were unknown for many of them, and it was very difficult to obtain considerable quantities of timber that would behave in the same manner as did a sample. Young planted rubber from local seed succumbed to attacks of South American leaf blight, and insect pests which were unknown as enemies of *Hevea* in the wild, became devastating. The company was forced to abandon plans of large-scale expansion of rubber planting until it can obtain a satisfactory control of some of these plagues.

Only a small portion of the planted area of the United Fruit Company *Hevea* was of the improved material. When the Stevenson Scheme failed and rubber prices again dropped, this company realized that the low yields which could be obtained from unimproved trees could not support profitable operation. The company abandoned its plantations in Panama and Costa Rica, at which time they were apparently healthy. However, when the author arrived in 1935 with Mr. B. E. Bookout, Agricultural Superintendent of the United Fruit Co., remaining trees were heavily defoliated by *Dothidella ulei*. There is still no record of the trail by which the disease reached Panama and Costa Rica. This plantation in Costa Rica was later purchased by the Goodyear Rubber Plantations Company and became the base for their studies of control methods for South American leaf blight.

The Goodyear Rubber Plantations Co. had established a plantation on the island of Mindanao, in the Philippine Islands, in 1928 as a first step towards eventual planting in the Americas. The better clones from all sources were established there as soon as they were available. When, in 1934, the International Rubber Restriction Agreement limited the export of rubber from all the major producing centers of the world, the agreement also prohibited movement of rubber-producing plants out of the countries within the agreement. The Philippine Islands had not joined the agreement, and the Goodyear collection of clones was the largest outside the restricted area. Impending conflict in the Pacific area, the danger of having the entire source of their chief raw material come from a small portion of the globe, and the danger inherent in having this material controlled by a producer's association, were factors which were influential in a consideration of the possibilities of plantation-scale production of rubber in the American tropics. High yields that could be obtained from the clones which the company had on the Philippine estate should off-set the wage differential between the American tropics and the plantation areas of the East where the majority of rubber production was from low-yielding trees.

Leaf Disease Control Essential for Permanent Plantations in the New World

A shipment of plants of 1,100 clones to a new estate established on the borders of Gatun Lake in Panama was to be the base for distribution of planting material, and commercial production was

planned for an estate in Costa Rica. The discovery that South American leaf blight had arrived in Costa Rica before we did had a destructive effect on plans for the immediate building of a plantation for commercial production. A program leading to control of this fungus became immediately essential if plantations were to hope for successful survival at any point in the hemisphere.

A survey trip to Trinidad, the Guianas —where Stahel had for many years studied this disease—and to the Ford plantations in Brazil, brought little encouragement of attempts at control of the fungus with fungicides. Favorable climatic factors in the Tapajos area had permitted eastern clones, which the Ford Plantations had imported before the Restriction Agreement had discontinued access to them, to make some growth in spite of seasonal damage. Dr. J. R. Weir had attempted to offset this damage by budding at about six feet above the ground with buds of *Hevea guianensis* Aubl., and from them to obtain crowns with some resistance to the disease. This procedure worked well in favorable climate where the eastern clones could reach a height for top-budding with little damage by the disease. It was not the answer to our problems in Costa Rica and Panama, however, where the disease stopped growth of the trees and reduced their vigor long before they were large enough to be given a resistant crown. The Ford staff had made another observation which had outstanding value to our program and which gave us the courage to proceed with our battle against the fungus. They had found that a seedling population collected from the frequently inundated islands near the mouth of the Amazon, and also a population collected from some of the cloud-bathed foot-hills of the Andes along the Acre River, had mean resistance levels to the disease which appeared to be higher than the extreme resistance exhibited among the Tapajos seedlings. Since the Tapajos population was the basic stock of our plantations and of the improved clones, it became necessary to return to the Amazon for the genes that would give our trees the resistance to protect them from the disease.

Permanent Plantations Require High Yields Too

The resistant populations were very low in their yield levels. That from the region at the mouth of the Amazon was later found to average only half of the yields of the unselected Tapajos seedlings. Obviously a plantation could not compete with high-yielding Indonesian estates when planted with such material any better than could plantations of clones without resistance to the disease. The staff of the Ford Estates utilized the climatic advantage which permitted them to grow the eastern clones to flowering size and intercrossed these clones with the resistant trees. Some seedling families with a very high level of resistance resulted from these crosses. Early yield tests of the seedlings promise that the eventual planting materials for plantations of *Hevea* in the Americas will have their origin among these crosses or those which were later prepared by Mr. L. A. Berry, Jr., who worked at the Ford Estates on a program cooperatively supported by the United States Department of Agriculture and the Instituto Agronomico do Norte of Belem-Para, Brazil.

When the war emergency placed the rubber plantation areas of the world in jeopardy, funds were appropriated to the United States Department of Agriculture to assist the development of a rubber plantation industry for our hemisphere. First, a survey of areas suitable for rubber growing was made, and cooperative agreements were reached with many of the American Republics, which insured a free interchange of improved planting materials and of information.

Fig. 5. (*Upper left*). Scaffolding erected to permit access to the flowers of high-yielding *Hevea* clones and thus to facilitate the making of cross-pollinations with pollen from high-yielding strains. This procedure carries the hope of combining satisfactory levels of yield and resistance in the same tree, and averts many budding and spraying operations.

Fig. 6. (*Upper right*). Hevea trees are tapped near the ground and climbing them is not necessary. A tapper can tap 400 or more trees per day on plantations.

Fig. 7. (*Lower left*). Tapping castilla trees requires strength and skill, and few can be tapped by one man in a day's work.

Fig. 8. (*Lower right*). A blight-resistant scion grafted on a high-yielding but blight-susceptible stock. The scion will develop a crown with healthy foliage for the latex-producing trunk which, in turn, has been grafted on a good rooting stock.

These have been of essential value to subsequent development of the plantation industry.

Before facilities for research were available the U.S.D.A. sent Dr. M. J. Langford to the Goodyear All-Weather Plantation in Panama. There he developed a spray procedure which gave very satisfactory control of the disease in nursery areas. Later, at Turrialba, Costa

FIG. 9. (*Upper*). A screened house provided for laborers on a plantation is much superior to the primitive dwellings of tappers in jungle areas.

FIG. 10. (*Lower*). A native in the rubber country of Brazil coagulating rubber in successive coatings on the end of a stick by repeatedly dipping the stick into a mass of collected latex and then rotating it in the smoke of a fire.

Rica, he adapted his equipment and procedure to give equally effective control of the disease on non-resistant trees which were planted at field spacing. This practice has become the keystone of the entire program of disease control. It made it possible in all climatic zones to protect the non-resistant high-yielding eastern

clones until they can be given a crown of resistant origin.

Dr. E. W. Brandes and Dr. R. D. Rands, at the Beltsville headquarters of the Bureau of Plant Industry (U.S.D.A.), and the staff of the Central Experimental Station at Turrialba, Costa Rica, under the direction of Dr. Ernest Imle, have maintained constant contact with the accomplishments and the needs of the research workers in each of the cooperating government and industrial groups. They cared for the distribution of scarce planting materials and technical assistance among the projects, and formed the clearing-house for information that originated at any point in the program.

War Emergency Leaves Hevea Plantations in Many New World Countries

Unfortunate as it was that the essential investigation had not been done before the emergency arose, the end of the war in the Pacific (and of the emergency) found the plantation culture of rubber firmly established in many republics of Tropical America. Dr. E. W. Brandes included in the introductory comments of the U.S.D.A. publication, "Cooperative Inter-American Plantation Rubber Development", the following table showing the extent of new plantation rubber at the end of 1945:

SUMMARY OF HEVEA PLANTINGS BASED ON INCOMPLETE REPORTS FROM COOPERATORS

Country	*Estimated acerage at end of 1945*
Brazil	16,000
Colombia	510
Costa Rica	2,400
Dominican Republic	30
Ecuador	...
El Salvador	...
Guatemala	1,129
Haiti	6,500
Honduras	813
Mexico	347
Nicaragua	125
Panama	125
Peru	68
	28,047

Reports from which the above table was compiled apparently did not always include rubber which had been planted in colonization projects or other small holdings. These were at times supervised by local government technical men and were in part financed by the government as a portion of the expense of setting up the projects. On page 70 of the report, "Caucho" (Rubber), of the Consejo Inter-americano Economico y Social (Inter-American Economic and Social Council) of the Pan-American Union, dated September, 1946, there is the following statement (translation—W.N.B.):

"At this date there have been planted 3,750 acres of Hevea rubber in Mexico, and it is expected that the number of planters, that is now about 650, will increase to more than 1,000 during the coming rainy season. Now the valley of el Palmar, Veracruz and the area of Tabasco Chiapas, in the south of Mexico, are the regions where rubber is being planted".

Mexico has the most active locally financed program of assistance to the small holders of rubber plantings that has yet been established in the Americas. It is the expressed aim of the agricultural authorities of that country to produce enough *Hevea* rubber in Mexico to meet the needs of their rapidly developing rubber manufacturing industry. They wish to protect their transportation facilities from future shortages of tires if a new emergency interferes with supplies. This report ("Caucho") also refers to the *Hevea* rubber planted in Haiti. The plantings there were largely made by the Sociedad Haitiano-Americana de Fomento Agricola (SHADA) as a contribution to our emergency supplies. It is reported that considerable portions of the area originally planted have been abandoned and that the areas which are being maintained amount to between 1,400 and 1,600 acres.

In Brazil *Hevea* plantations consist chiefly of the former plantations of the Ford Motor Company, which were sold

to the Brazilian government after the Ford Company ceased to manufacture tires and no longer needed a source of raw rubber for its factory operations. The plantations were largely made up of high-yielding eastern clones which had already been top-budded with resistant tops. Production has started on the estates, which contain a tremendous amount of valuable breeding stock from eastern sources and from all parts of the Amazon Valley. The plantations are being administered for the Brazilian government by Dr. Felisberto de Camargo, who also is Director of the Instituto Agronomico do Norte, at Belem. It is certain that under his direction the collection of planting material will be developed and will produce much valuable planting material for the plantations of the future.

Colombia has financed nurseries and some extension of *Hevea* planting in connection with a colonization program. Peru, Nicaragua, Guatemala and Costa Rica maintain cooperative experiment stations in which propagating material of the high-yielding clones from the East and clones for top-budding with tested resistance are available. In some cases plants and budwood from these nurseries are given to the planters who wish to establish small areas of rubber. Elsewhere they are sold at a nominal cost.

The United Fruit Company has planted high-yielding and top-budded *Hevea* on a plantation scale in Honduras, Guatemala and Costa Rica, within its program to substitute new cultures for bananas on land which will no longer serve for that crop.

Planting has been completed and experimental-scale production has begun on the 2,500 acre plantation of the Goodyear Rubber Plantations Company, at Cairo, Costa Rica. Results of a tapping test made on young top-budded trees of about 20 clones were closely comparable to the yields from the same clones when they had their own tops and were first tapped in Sumatra. Although the top used for top-budding had a very low potential yield, it apparently had little influence on the ability of the tissues within the cortex of the trunk to elaborate latex. Similar results were obtained from tapping tests conducted at the Ford Plantations in Brazil and among the few trees which have been tapped on the plantation of the Interamerican Institute of Agricultural Sciences, in Panama.

Local Manufacturers Provide Best Market for New World Plantations

The plantations which have been established in various countries of the New World have a potential productive capacity roughly equivalent to the entire output of rubber in this hemisphere during pre-war years, but they do not increase the probable export of raw rubber that is to be expected from this region. New rubber factories, which at present manufacture the most popular sizes of tires and varied mechanical goods, have been built in several of the rubber-producing countries. The demand of these factories for rubber will often increase faster than will production from the plantations which have so far been established. Increased accessibility of formerly remote areas has been brought about by increased demand for agricultural production, by construction of improved roads and by the availability of "Jeeps" which can negotiate roads that were formerly passable only for burros and ox-carts. Even the stand-by of transport into wild areas, the ox-cart, has been transformed and rides on rubber instead of rumbling along on steel-rimmed wooden wheels. The demand for rubber tires for these carts knew no bounds when it was demonstrated that a yoke of oxen could haul double the quantity at a faster pace on rubber tires, when they replaced the narrow steel-

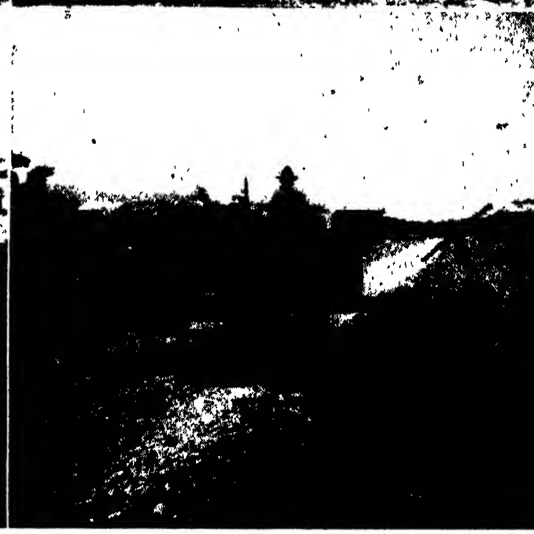


FIG. 11. (*Upper left*). Dr. M. J. Langford (right) pointing out to Mr. J. J. Blandin, Dr. R. D. Rands and the author, the superior resistance of one clone from a jungle selection.

FIG. 12. (*Upper right*). A seedling of *Hevea brasiliensis* budded with a bud from a high-yielding clone being removed from the nursery bed for transference to the field planting.

FIG. 13. (*Lower left*). Nurseries of root-stocks or of non-resistant budwood can be protected from South American leaf-blight if properly sprayed.

FIG. 14. (*Lower right*). All-weather roads are important features in high yielding plantations, for tappers can not carry the latex from a day's task in such areas when the trees are mature.

rimmed wheels. As in the rest of the world, new uses are found for rubber each year here in its native home. Production that was formerly sufficient no longer suffices. The new plantation areas will insure that a supply will always be at hand, and if this is insufficient for the growing local demand it will nevertheless be a powerful stimulus to the planting of new rubber areas.

Small Farms Will Provide Much of the American Rubber Production

It is improbable that we are to see the development of much of the rubber industry in the American Republics take the form of large corporate-owned areas, as were the chief production units in other regions. The social structure of many countries of the Americas, their relatively small populations, the popu-

larity of labor legislation and the love of land ownership on the part of the laborers, all oppose the establishment of this type of productive unit. Rubber production, to adjust itself to the permanent economy of these countries, will have to come from small family-size production units. Such small-scale production units began their development in Malaya and Indonesia after rubber had been established as a plantation crop in those areas. Production from the small areas has constantly grown at a higher rate than has plantation production, and it appears probable that, with the exception of latex and other products requiring the attention of a chemist or technical man during processing, it will be small farms which will produce most of the world rubber of the future.

Rubber as a crop has many attractive features for the owner of a small plot of land, in the areas where it can be grown. When the trees are mature a crop can be harvested at any time of year and can be converted into cash within one or two weeks. The product has a high value per pound, it can be stored without serious deterioration, market grades are easily determined, and the price is clearly established by the world market. Trees can be tapped intensively to give greatly increased yields when there is a sudden need for income, or the trees need not be tapped and will not suffer if other work demands one's time. Loss of a crop as a result of sudden showers wipes out only the labor of a single day, and does not destroy the work of a season, as bad weather during the harvest of a crop of beans or rice may do. When the trees are mature they require little care, and with reasonable caution during tapping operations will continue to yield rubber for 25 years or more.

Two factors, aside from the normal inertia and conservatism of agriculturists the world over, are chiefly responsible for the slow acceptance of rubber as a crop among the small farmers of the Americas. The lack of capital to support the clearing of land, the purchase of planting material, and the upkeep of the trees through five unproductive years is first apparent. This problem was met by the Indonesian planters through the use of food crops planted among the young rubber trees until the latter shaded the ground and could battle the undergrowth alone. In a series of experiments on the estates of the Goodyear Rubber Plantations Co., in Costa Rica, we learned that inter-crops among young rubber trees do not give as serious competition with the growth of the trees as do native plants. Planting, top-budding and growth were all considerably improved in areas which were cultivated with inter-crops.

Planting and Budding Technique

The native planter interested in rubber cultivation will find the chief drawback connected with this crop, at the present time, is that he is incapable of following through the many complicated horticultural practices that are now required to get a resistant and high-yielding *Hevea* tree planted in his property. A nursery, preferably planted with seeds from a resistant population, containing from four to eight seedlings for each tree that it is ultimately desired to plant, must be established a year or more before planting begins. At the same time, a few stumps budded with high-yielding clones are planted to provide multiplication of budwood. These must be frequently treated with fungicidal spray, if the area is one in which disease is present. When the seedlings are about one-half inch or more in diameter they are budded at a point about four inches from the ground with buds from the multiplication area of high-yielding clones, and the top of the seedling is cut off to force growth from these buds. The shoot which develops must be protected with spray until

it has brown bark on about six feet of the trunk. A bud of a tested resistant clone, known to have a high growth rate and a low rate of wind breakage (when used as a crown), is then budded into the top of the high-yielding trunks at a point about six feet above the ground. The top of the trunk is removed to force growth from the resistant bud, and if weather is perfect (moist–dull) for planting, the budded stumps can be taken to the field areas for planting. For more security the trees should remain in the nursery until there is approximately two feet of brown wood on the resistant shoot. The tree is now two years old, heavy, and presents a problem of needing large planting holes, careful planting procedure and good weather to insure a full stand.

Competent horticulturists have a difficult time planning the above procedure to supply the necessary quantity of planting material when the weather is suitable and the land cleared for planting. The man who contemplates beginning his rubber planting with 500 trees or less is completely baffled. Usually he will not plant a new crop unless he can get the trees in a condition in which they can survive with the minimum amount of care.

FIG. 15. (*Left*). The partially defoliated appearance of a young rubber tree infested with the South American leaf-blight disease.

FIG. 16. (*Right*). Corn which has been improved by inbreeding and hybridizing makes a profitable inter-crop for young rubber plantations.

Plant Breeders Must Combine High Yields and Resistance to Encourage Small-Farm Planting

When we obtain from the new crosses between Eastern and Amazonian selections, some clones which combine yield and resistance to a satisfactory degree to give us planting material which will produce 1,500 pounds of dry rubber each year, and which will not need to be sprayed or top-budded, we can hope to see a small-farm native rubber planting of considerable proportions develop in the most suitable areas of the Americas. Until such material is ready for distribution small areas will be planted with rubber only in countries which distribute planting material that is already top-budded, or supervisory and technical service which constantly checks to see that spraying and budding are done at the proper time and with correct materials.

The small-scale planter can process his

rubber into smoked sheets and make a product that answers the requirements for the major uses of rubber with cheap and simple equipment. It is necessary for him only to get the latex to the coagulating tanks or pans without incipient coagulation, to strain the latex several times, to settle out particles of sand, and to use a uniform amount of acid for coagulation; all this to turn out a quality of rubber equal to that made with the best processing machinery and acceptable in the market at top prices.

We have discussed the advantages of rubber for the man who plants from one to five hectares of rubber which he can care for and tap with the members of his family. He has no need to consider the charges for hospitalization, overtime, vacation or dismissal pay that social legislation requires of those who hire labor. Can plantations compete with him? We can answer only that they have always been able to do so in the rubber areas of Malaya and Indonesia, where the two were adjacent. This was made possible by the research which was maintained by the estates. They utilized labor-saving practices, improved planting materials, selective thinning, factory and transportation machinery and other means of lowering production costs. The owners of the small-scale units at no time developed any of these labor-saving practices and seldom borrowed the practices which were found effective on the estates beside them. This lag in the use of improved planting materials and practices on the part of the small farms gave the plantation operator a sufficient margin of efficiency to cover his costs for management and research with enough margin to frequently permit a profit. Important as research was to the estates in the Malayan region, it is essential to plantations which will be planted in the Americas. High labor costs, relative to former costs in the Malayan area, can be offset only by planting new plantations for the minimum capital outlay, planting them with material which will combine high yields with resistance, and by the use of only the most efficient production methods. Continuous research will be required to maintain an advantage that is gained over competitive areas, whether the competitors are adjoining small estates or large plantations in other places.

There is another reason to look forward to the maintenance of rubber production from a certain number of plantations of medium or large size. There has been a considerable increase in the number of uses for rubber during the past few years, and the Americas are more available to our factories than are other producing areas. Many of the new uses require that the rubber processing start almost as soon as the latex leaves the tapping cut. For example, in the preparation of liquid latex, an anti-coagulant is often added to the cup. Use of liquid latex, either in natural or concentrated form, for the preparation of latex-foam rubber for upholstery was one of the fastest-growing new uses of rubber before the war. The latex for this material must arrive at the manufactories without the slightest incipient coagulation. The clone, the tapping-system, the weather and the time of arrival of the latex at the processing center all affect the quality of the latex and the amount of anti-coagulant to be added. All factors must be as favorable as it is possible to get them to deliver a superior latex to the factory. Sufficiently close control to get this latex in satisfactory condition usually requires a well-staffed plantation organization with a chemist always checking procedure. The small-scale planter can not provide this care. Other products, such as rubber-sheets or latex with low-water absorption, soft rubber, crumb rubber and rubber suitable for the preparation of clear films for the prevention of humidity exchange in prod-

FIG. 17. Three-element Hevea trees in plantation. Below the bulge near the ground is a root of resistant stock. Between this lower bulge and the curved portion of the tree slightly above the head of the man is a trunk of a high-yielding, non-resistant clone. The top of the tree is of another clone which is resistant to the leaf-blight. *(Courtesy Dr. E. W. Brandes, U. S. Bureau of Plant Industry.)*

ucts ranging from delicate foods to airplane engines, all require the assistance of a technical staff in their preparation. Other products were being developed before all natural rubber was required for war equipment, and we can look forward to the appearance of many new uses of rubber when fresh latex is again available to our chemists.

In many of these uses synthetic materials have not been successful in replacing the natural product. It will still be necessary to have available a suitable quality of fresh latex of the necessary specifications if we are to continue to keep up with the new uses which have been found for some of these rubber articles. At the present time the plantations which are reopening in Malaya are again becoming the source of this latex for specialized products. Western Hemisphere sources have not yet achieved sufficient productive capacity to meet the demand from the production of these articles, and cannot do so until plantations are much larger than any which are so far established.

Will the demand for autonomy extend to Malaya? Will we continue to have a trade with that area in sufficient volume to permit the former low freight rates? Will the demand for increased wages in Malaya offset present low production costs? Will trade restrictions interfere with the free access to these areas, and will our technical workers be permitted freedom to work there? It is in the answers to these political and economic questions that lies the immediate future of the use of rubber in our newer products. In their solution we will be able to find the answer to our question, Is there a profitable future for rubber plantations in the Americas?

A greater amount of clairvoyance or skill in prophecy than is possessed by the author will be required to assure us that trade and production in Malaya will become re-instated on a basis that will permit uninterrupted supplies of these essential grades of rubber to reach us from that source. Renewed difficulty in getting supplies from that already-established source will become the basis of further interest in building an alternative source from plantations in the Americas.

Many Factors Favor Permanent Hevea Plantations in the Americas

We now know that it is possible to establish these plantations in the tropical portions of the Western Hemisphere and to obtain from the trees in them similar or even better growth and yields than we had in our best plantations in Indonesia or Malaya. Slight increases in planting costs will protect the trees during their lifetime from the principal disease of *Hevea*, caused by *Dothidella ulei.*

Productive life of trees planted in plantations of the Americas will probably be much longer than that of trees in the Eastern plantations, and the cost of maintaining the trees in a healthy condition will be considerably less here. For some reason that has not yet been discovered, the *Fomes* group of root diseases, which greatly shortened the producing life of rubber trees both in the Asiatic tropics and in Africa, has not damaged *Hevea* trees in the plantations of the Western Hemisphere to a serious extent. Other pathogens that were at times serious and difficult to control in the East, *e.g.*, *Corticium salmonicolor* (Pink Disease) and *Oidium* sp., do not appear to be as virulent in the tropical areas of this hemisphere.

The end of the war and of the emergency in the supplies of natural rubber from former sources finds us with a small but firmly established rubber-plantation industry in the tropical countries of the New World. Generally this new industry is in the hands of governmental or industrial agencies which are sufficiently well financed to insure that the areas will

be maintained until they are able to operate from profits. Expansion from this nucleus into a major new plantation industry for the Americas will without doubt await the solution of the political and social problems of the areas of Indonesia which contain a major portion of our former rubber-producing plantations. Growth of a demand for a reliable source of latex and rubber for new products, and of the requirements within Latin-America for a raw material for local rubber factories may be sufficiently rapid to force new planting in this area, even before the future economic status of raw rubber in the world's markets is fully established.

Rubber as a plantation crop for the Americas has been established and will remain.

Utilization Abstracts

Insecticide from Southern Pine Stumps. In 1940, one year before Pearl Harbor, the Hercules Powder Company announced the production of "Thanite," an insecticide made from southern pine stumps and named after the Greek word "thanatos" meaning "death." In chemical parlance Thanite is the isobornyl ester of thiocyanate, a terpene derivative obtained from stumps of pine trees as part of the wood naval stores industry. In this industry pine stumps, after being lifted, are shredded by machinery and then extracted to yield a wide variety of products, mainly rosin, pine oil and turpentine. It is from the last of these that Thanite is derived. The investigations which led to the discovery resulted from efforts to find among the derivatives of pine oil and turpentine, either an activator for the commonly used pyrethrum or a derivative which of itself would serve as an effective insecticide and render American industry independent of foreign sources of pyrethrum. Japan had long been the single large source of this spray material, imported into this country as an extract. The British Kenya Colonies in Africa were a secondary source. Involved in the research that led to this development were Kansas State College, University of Delaware, University of Florida, Rutgers University, Cornell University and scientists of the U. S. Department of Agriculture and of other insecticide manufacturers than the Hercules Powder Company. (*L. P. Kilileu, Chemurgic Papers, 1946, Series No. 3, No. 450*).

Vegetable Oils in Soaps. In 1945 the American soap industry consumed more than two billion pounds of oils, fats and fatty oils. Of this amount, 250,000,000 pounds were derived from vegetable sources; the remainder from tallow, grease, fish and imported oils. Before the war the manufacturers of liquid or paste soaps (which cannot be molded into cakes but are shoveled out of a barrel and dissolved for use as a liquid out of dispensers) used principally imported coconut oil and potash as well as various other oils from foreign plant sources, *viz.*, tea seed, rubber seed, hemp seed and Japan wax. These bland oils were preferred because of their high lauric acid content providing the two ingredients "glyceryl laurate" and "glyceryl myristate" which give rich sudsing and quick lathering properties. Cohune nuts [*Orbignya Cohune*] from Mexico and Honduras, babassu nuts [*Orbignya speciosa*] and murumura nuts [*Astrocaryum Murumura*] from Brazil provide similar oils.

The great need for these bland oils could possibly be better met by greater utilization of farm- and orchard-produced seeds, nuts, fruits and beans in America—tomato, grape, walnut, pecan, apricot, prune, grapefruit, orange, peach, melon, cotton, peanut, corn, soybean, olive, perilla, castor, sunflower, sesame and avocado.

A good substitute for the bland fatty acids derived from seeds and nuts, is tall oil, a by-product of the paper-pulp industry. (*D. J. Bachrach, Chemurgic Digest 5(13): 232. 1946*).

Effects of Manuring on Growth and Alkaloid Content of Medicinal Plants

Nitrogenous fertilisers, in particular, have been found to stimulate growth and increase the alkaloid content of Atropa Belladonna.

G. M. JAMES
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Introduction

THE effects of manuring with organic manures and inorganic fertilisers on alkaloid-forming plants have been studied in considerable detail during this century because of the important medicinal products which are obtained from many of these plants. Most of the work came from the continent of Europe, and some from the U.S.A., but of recent years the urgency of war has stimulated work in Great Britain also, and it may be of interest to workers in the U.S.A. to have the European work, including recent work in Great Britain, summarised as well as that of their own country. In the present paper it is proposed to deal especially with the alkaloid-producing drug plants, with only brief reference to relevant work on other alkaloid-producing plants such as tobacco.

Most of these plants, including *Atropa Belladonna* L., *Hyoscyamus niger* L. and *Datura Stramonium* L., will grow in North Temperate regions, and are cultivated in both Europe and North America; they also grow as native or naturalised wild plants in parts of both continents. Cinchona is, of course, tropical in its habitat, and is cultivated in the more tropical parts of the U.S.A. and of the British Commonwealth and U.S.S.R.; it is still collected in its native habitats in the Andes.

As early as 1908 Carr and Reynolds were publishing work on the cultivation of *Atropa Belladonna* in the U.S.A., and about the same time several workers in Germany, Austria and Hungary were investigating the effect of farmyard manure and "artificial fertilisers" on the alkaloid drug plants. At an early stage it became evident that at least three separate effects had to be taken into account: the effect on growth of the plants and so on the total yield of the plant material; the effect on the alkaloid content of the plant expressed in milligrams; and the effect on the "assay", or alkaloid content, expressed as a percentage of the dry weight of the plant. These three aspects will now be considered in more detail.

Effect of Manuring on Growth and Yield

Most of the earlier work in Europe was concerned with *Datura Stramonium* and *Hyoscyamus niger*, presumably because *Atropa Belladonna* grows so freely as a wild plant that its cultivation was considered to be of minor importance. There is very general agreement that the effect of farmyard manure and other nitrogenous fertilisers of various kinds is to increase the growth of individual plants in both species and so to increase the total yield of plant material. In 1911 yields from *Datura Stramonium* were reported as increasing from 23 kg.

per 100 square metres on unmanured land to 33 kg. per 100 square metres on land which had been dunged with farmyard manure (15). The investigators also reported that such treatment increased the ash content of the material from 16% to 18% of the dry weight. These results were confirmed and extended in 1923–1924 by others (9) who tried the effect of cow manure and also of various nutrient salts, and found that rich nitrogen manuring of all types tends to raise the yield. In 1930 Boshart (1) again reported increased yields as a result of dunging, but emphasised the facts that balanced manuring is necessary for healthy growth, and that unbalanced manuring, especially with potassium but also with phosphorus and magnesium, may lead to a decrease of yield. Others (5) in 1932 confirmed the importance of balanced manuring for healthy growth; working with *Datura Stramonium* and *Hyoscyamus niger*, both annual and biennial forms, they used a soil poor in humus, dunged the previous year, containing 10.47% $CaCO_3$, 0.2% N, 0.14% P_2O_5, 0.57% K_2O, and added nitrogen, phosphorus and potassium fertilisers; nitrogen was applied as $NaNO_3$ equivalent to two gm. N per square metre, phosphorus as superphosphate equivalent to six gm. P_2O_5 per square metre, and potassium as various potash salts equivalent to four gm. K_2O per square metre. The dry weight as total harvest in grams is given in Table I.

TABLE I

EFFECT OF MANURIAL TREATMENTS ON DRY WEIGHT OF *Datura Stramonium* AND *Hyoscyamus niger*

Treatment	D.W. = Total harvest in gm.		
	D. Stramonium	*H. niger*, annual	*H. niger*, biennial
No addition	290	430	560
P	310	450	510
K	320	420	470
N	270	570	730
NK	280	600	830
NP	370	590	700
PK	260	500	690
NPK	350	630	700

From these figures it is evident that, although nitrogen manuring usually increases yield, especially with *Hyoscyamus*, unbalanced manuring with other nutrients tends to decrease yield, or only to increase it by a comparatively small amount. The balance between the three nutrients is a much more important factor, especially the balance between nitrogen and phosphorus with *Datura Stramonium*, and between nitrogen and potassium with both forms of *Hyoscyamus niger*.

In 1936 a review of experimental work (4), especially in Austria and France, on a number of drug plants, including *Datura*, *Atropa*, *Hyoscyamus*, *Aconitum* and *Lobelia*, stated that it was generally agreed that in all these genera, manuring, especially rich nitrogen manuring, increases growth and so yield of plant material. Organic manures, such as horse manure and fertilisers of the type of nitro-lime, are especially effective with *Atropa Belladonna*. Work reported in a later review (3) showed that ammonium sulphate or calcium nitrate is just as effective in stimulating growth of these plants as stable manure or compost. Dafert also reported a series of experiments by Salgues on a variety of plants, growing on different types of soil. The plants included *Hyoscyamus niger*, *Colchicum autumnale* and *Aconitum Napellus*, and Salgues was able to show that the type of soil and also the age of the plant had a very definite influence on the effect of a particular manure. For example, a series of experiments was carried out with *Hyoscyamus niger* (biennial), using nitrogen, potassium and phosphorus fertilisers with an unmanured plot as control; four types of soil

were used, containing (*a*) silica and lime, (*b*) silica and clay, (*c*) clay and lime, and (*d*) silica only. In the first year the highest yield of leaves per plant on silica-lime soil came from the unmanured plot; on silica-clay soil from the nitrogen-manured plot; on clay-lime soil from the nitrogen-manured plot; and on siliceous soil from the nitrogen-manured plot; in the second year the potash-manured plot on silica-lime gave the highest yield and also on siliceous-clay soil. On clay-lime soil nitrogen manuring was again highest, but potash was best on siliceous soil. In the present author's opinion it is doubtful that a sufficiently large number of replications was used to give really reliable results, but this series of experiments is useful in indicating the great importance of the nature of the basic soil in practical cultivation. In experiments with *Colchicum,* phosphorus gave better yields than nitrogen, especially on lime-containing soils.

Dafert reported that in his own experiments manuring generally led to increased yield of green plant material and that the most beneficial manurial substance depended on the particular plant in question.

In 1939 Ozterov (17) reported that application of potassium nitrate to plants of *Cinchona succirubra* raised from vegetative cuttings increased the yield, whereas ammonium salts may lower yield, owing to damage to the plant. Yield was also increased by phosphorus, but most of all when a correct balance was obtained between nitrates and phosphorus salts. He also reported considerable variation in the effects shown on soils of different types, thus confirming the work of Salgues with other alkaloid-forming plants.

In 1942 W. O. James, working at Oxford, England, reported the results of a series of field experiments and pot cultures with *Atropa Belladonna.* In the field plots on a clay-lime soil, half were top dressed with sulphate of ammonia at the rate of 1½ cwt. per acre, applied during the second half of May. The plants were second-year plants and were sampled and cut down at the end of the first week in July. They sprouted again rapidly, especially on the dressed plots, and were cut again during the second week in September. No significant difference was found between manured and unmanured plots in the first sampling, but in the second sampling, the dry weight of leaf per plant was increased by 68%, on the average, on the plots dressed with sulphate of ammonia, and the number of new sprouts per plant was increased by 30%. In the pot experiment a good alluvial soil mixed with an equal volume of washed sand was used as a base, and seedling plants were used. When they were established, half the pots were dressed with ammonium sulphate (13 gm. per pot), and the dressing was repeated in June and again in August. On hot days during July and August the plants in the dressed pots tended to wilt, while those in undressed pots did not, but by the end of August the growth of the plants which had a dressing of sulphate of ammonia was much greater than that of the plants which had no dressing. The plants were harvested at this time and the dry weight per plant was increased from eight gm. with no addition of sulphate of ammonia to 20.3 gm. with sulphate of ammonia. In 1943 a field experiment was carried out with top dressings of sulphate of ammonia at the rate of 0, 1, 2, 4 cwt. per acre and the results are summarised in Table II.

It is evident from these figures that ammonium sulphate causes an increase of yield with moderate dressings but a fall at higher concentrations. A pot experiment was carried out at the same time using seedling (first year) belladonna plants and four different nitrogenous fertilisers—sulphate of ammonia,

TABLE II

EFFECT OF SULPHATE OF AMMONIA ON DRY WEIGHT OF *Atropa Belladonna.* DATA OF W. O. JAMES *et al.*

Cwt. $(NH_4)_2SO_4$ per acre	0	1	2	4
Gm. d.w. per plant	26.3	30.3	24.8	24.7

nitrate of soda, nitro-chalk, dried blood —and a control set with no additional nitrogen. The top dressings were calculated to provide the same weight of nitrogen. Table III summarises the dry weights obtained.

It is evident that all the nitrogenous fertilisers caused large increases of growth of stem and leaves, which is in agreement with the results of earlier workers; but fertilisers containing nitrogen in the form of ammonia, such as ammonium sulphate and nitro-chalk, cause a decrease in dry weight of roots, whereas other nitrogenous fertilisers cause a marked increase.

Experiments reported in 1944 and 1945 with the mineral fertilisers potassium, calcium and phosphorus, supplied in addition to nitrogen, indicate that these elements have little effect on growth compared with nitrogen, though lack of phosphate seems to involve poorer leaf development, and lack of calcium a

TABLE III

EFFECT OF VARIOUS NITROGENOUS FERTILISERS ON DRY WEIGHT OF *Atropa Belladonna.* DATA OF W. O. JAMES, REARRANGED

Treatment	Gm. d.w. of leaf per plant	Gm. d.w. of stem per plant	Gm. d.w. of root per plant
No nitrogen	9.8	4.9	23.1
Nitro-chalk	23.2	11.9	21.7
Ammonium sulphate	23.6	10.4	22.3
Sodium nitrate	20.9	11.9	35.1
Dried blood	23.2	10.7	25.0

poorer root development. James confirms the emphasis laid by earlier workers on the need to secure a reasonable balance when mineral fertilisers are used, as well as rich nitrogen supply.

To summarise, it may be said that there is very general agreement that rich supplies of nitrogen increase growth of stem and leaf, and so tend to increase the yield of plant material, but that high concentrations of nitrogen in the form of ammonia may cause decrease of yield, and especially a decrease in the dry weight of roots produced. Other mineral elements have much less effect on growth than nitrogen, but phosphorus tends to increase growth slightly in most of these plants, and there is some indication that calcium may have a similar effect on the root systems, especially of *Atropa Belladonna.* In all the more recent work it is emphasised that a balanced fertiliser is essential for healthy growth, and that overmanuring with any one substance (except perhaps nitrogen in the form of nitrate) may be harmful. The effect of all mineral fertilisers is greatly influenced by the composition of the soil in which the plants are growing, and possibly also by the age of the plant. Others (14, 21, 22) have also shown recently that the pH value of the soil has an important effect on the growth of *Atropa Belladonna* and other alkaloid-forming plants, although another worker (16) in 1928 found little effect of pH with tobacco plants.

Effect of Manuring on Alkaloid Content

Results of work investigating the effect of various manures on the alkaloid content of these plants are much less consistent than those dealing with growth and yield. The alkaloid content may be expressed as a percentage of the dry weight of the plant material, as in the official methods of assay, or it may be given as milligrams of alkaloid per plant

or per square decimetre of leaf surface, and various workers have expressed their results in different ways.

Before considering the effect of manuring on alkaloid formation it is essential to point out that changes in the dry weight of the plant will affect the "assay", or alkaloid expressed as a percentage of the dry weight, even if there is no change in the rate of alkaloid formation or in the amount of alkaloid accumulated in the plant. Thus an increase in dry weight, with no change in alkaloid formation, will cause a decrease in "assay", while a decrease in dry weight will cause a corresponding increase in "assay"; it follows that assay values are not a satisfactory basis for the study of changes in the amount of alkaloid stored by the plant, unless corresponding changes in dry weight are also known. This is rarely possible in an experimental study extending over a period of time, and a safer basis for comparison is the total alkaloid content, expressed as milligrams per plant. This fact has often been overlooked in published papers, and erroneous conclusions have often been drawn from "assay" values as a result.

In a paper already referred to (15), it was reported that dunging with farmyard manure had no significant effect on the assay of *Datura Stramonium*, but some years later the view was expressed (9) that nitrogen manuring favours alkaloid production in this species. After further investigation the latter author (1) came to the conclusion that unbalanced manuring leads to a decrease in alkaloid formation, especially with potassium salts. In 1932, in the series of experiments described in the preceding paragraph (5), analyses of experimental plants of *Datura* and *Hyoscyamus* confirmed the need for balanced manurial treatment. Nitrogen manuring appears to favour alkaloid formation, especially in the biennial form of *Hyoscyamus niger*, as both assay and total alkaloid are increased; the total alkaloid increases from 83 mg. to 117 mg. per square metre, and the assay from 0.0135% to 0.0152%; these figures are the means of four experiments quoted in each case. With the annual form of *Hyoscyamus* the alkaloids increased from 66 mg. to 83 mg. per square metre, but the assay decreased from 0.0146% to 0.0139%. With *Datura Stramonium* there was no significant difference in either assay or total alkaloid as a result of nitrogen manuring. Unbalanced manuring with potassium or phosphorus gave very erratic results, with a slight indication of lowering of both assay and alkaloid content, especially with *Datura* treated with potassium. In their summarising report of 1936, the authors say that there is general agreement that assay is little affected by nitrogen manuring in both *Datura Stramonium* and species of *Aconitum*, but that in *Lobelia* there is a small but definite reduction of assay as a result of nitrogen manuring. As pointed out earlier in this section, this might be a result of an increase in dry weight, with no change in alkaloid formation. *Atropa Belladonna* and *Hyoscyamus niger* seem to behave alike, and results reported by different workers are contradictory. Little or no effect is found by some investigators, while others report increase of assay with heavy nitrogen manuring. Boshart and Klan agree that unbalanced potassium tends to reduce alkaloid content, and Klan adds that phosphorus, magnesium and calcium also decrease assay unless in balanced mixtures. In a later report Dafert (3) devoted considerable attention to a long series of experimental results published by Salgues, which indicates a possible explanation of the contradictory results published by earlier workers. Salgues used various types of soils as culture media and then added different manures, and was able to show that the effect of the manurial treatment

was very greatly influenced by the type of soil. His results indicate that with biennial ***Hyoscyamus niger*** nitrogen manuring leads to an increased assay only on heavy clay-containing soils, but that on light soils, without clay, and with or without lime, there is a decrease in assay as a result of nitrogen manuring. There is a consistent reduction of assay with unbalanced potassium manuring, and either reduction or very little effect with unbalanced phosphorus. Salgues also noted an age effect; the differences were greatest in the first year of growth, and much less in the second year.

The effect of the manurial treatments also varied with the different species examined, and also in different parts of the plant. For example, phosphorus manuring gave better results than nitrogen manuring with *Colchicum*, and this effect was especially noticeable in soils containing lime. With *Aconitum* the alkaloid content of the tuber was increased as a result of added potassium, though only if there was sufficient phosphoric acid present also; the alkaloid content of the leaves was most increased by application of nitrogen.

Preliminary experiments by Chanduri were also quoted in this review, indicating an increase in alkaloid content of *Atropa Belladonna* as a result of treatment with the ammonium salt of asparaginic acid, but this result seems to be of more theoretical than practical value at present.

Dafert himself considers that normal balanced manuring does not usually increase the alkaloid content of these plants, but that such an increase is usually due to unbalanced manuring with the particular nutrient that best suits the plant concerned.

It is of interest at this point to note that several workers (*e.g.*, 6, 16) have reported considerable increases in the nicotine content of tobacco leaves as a result of nitrogen manuring, especially with ammonium salts. Dawson states that heavy doses of ammonium salts may cause ammonia damage to the plants, but that in spite of this the percentage of nicotine is high.

The reports of the Oxford Medicinal Plants Scheme, whose research work is directed by W. O. James, show consistent increases in both assay and total alkaloid in *Atropa Belladonna* growing on clay-lime soils as a result of nitrogen manuring. In 1942 a mean increase in assay from 0.44% to 0.48% was reported for plants grown on field plots, and from 0.21% to 0.30% for plants grown in pot cultures. The total alkaloid increased

TABLE IV

EFFECTS OF DIFFERENT RATES OF APPLICATION OF AMMONIUM SULPHATE ON THE ASSAY AND TOTAL ALKALOID CONTENT OF PLANTS OF *Atropa Belladonna*. DATA OF JAMES *et al.*

Cwt. $(NH_4)_2SO_4$ per acre	0	1	2	4
l-hyoscyamine % D.W. = assay	0.29	0.30	0.35	0.47
Total alkaloid expressed as mg. *l*-hyoscyamine per plant	76.3	90.9	86.8	118.1

in the pot culture plants from 17 mg. per plant to 60 mg. per plant, this figure being the mean of ten experiments. In 1943 the experiments were designed to test the effect of different strengths of top dressings of ammonium sulphate, and showed that assay and total alkaloid values rise, even with applications of ammonium sulphate which decrease the yield. This is clearly shown if the data given in Table IV are compared with those in Table II.

The effect of nitrogen manuring on alkaloid content in *Atropa Belladonna* being so striking, a series of experiments was carried out to determine whether different types of nitrogen fertilisers showed different effects. Effects on growth have been discussed earlier in the present paper, and the effects on assay

and total alkaloid content of different parts of the plant are summarised in Table V.

It is evident from these figures that all types of nitrogen fertiliser cause increase in both assay and total alkaloid per plant, although they do not always have a favourable effect on the dry weight (see Table III). The fertilisers which contain nitrogen in the form of ammonia (nitro-chalk and ammonium sulphate) gave smaller increases than those which do not contain ammonia (sodium nitrate and dried blood). In spite of the unfavourable effect on growth noted earlier of high concentrations of ammonia-containing fertilisers, both assay and total alkaloid are increased at all concentrations tested at any time. Ammonia damage to the plant can often be noticed in the form of scorching of the leaves, easily induced wilting, *etc.*, but in spite of this, alkaloid formation increases.

Experiments with plants on field plots instead of pot cultures showed less effect, probably because the untreated plots gave fairly high values, owing to the fertility of the soil. The total quantity of alkaloid per plant was always increased, and more so with nitrate than with fertilisers of the ammonia type, but the assay was more variable, and even showed a slight decrease in some cases.

Experiments with the nutrient elements calcium, phosphorus and potassium, in addition to nitrogen, indicate that the effect of these substances on alkaloid content is much less than the effect of nitrogen. The figures quoted in the reports for 1944 and 1945 indicate that assay is lowered by addition of unbalanced potassium in *Atropa Belladonna* and raised by addition of phosphorus. Calcium seems to have little or no effect on formation of alkaloid in this plant, although with clay-containing soils especially it has an effect on the general growth of the plant.

It is interesting to note that Ozerov (17) reports that with *Cinchona* plants raised from vegetative cuttings nitrogen acts as "a stimulator of alkaloid storing" and increases the alkaloid content of the plant when it is applied in the form of nitrate or of ammonia, in spite of visible damage to the plants, especially to young plants, by ammonia. Much earlier Broughton (1873) reported increase of alkaloid content in *Cinchona succirubra* and *C. officinalis* when mature trees were manured with either guano or farmyard manure.

Ozerov also reports that phosphorus has little effect on alkaloid percentage or may even reduce it.

TABLE V

THE EFFECTS OF VARIOUS NITROGEN TREATMENTS ON DIFFERENT PARTS OF THE PLANT OF *Atropa Belladonna.* POT CULTURES. DATA FROM W. O. JAMES *et al.* 1943

Treatment	Assay %			Mg. alkaloid per plant			
	Leaf	Stem	Root	Leaf	Stem	Root	Whole plant
No nitrogen	0.21	0.21	0.31	20.8	10.3	71.6	102.7
Nitro-chalk	0.29	0.24	0.45	67.7	28.3	94.6	190.6
$(NH_4)_2SO_4$	0.30	0.27	0.42	70.8	28.1	83.8	192.7
$NaNO_3$	0.40	0.28	0.39	83.6	33.3	136.9	253.8
Dried blood	0.42	0.24	0.53	97.5	25.6	132.4	255.5

Summary

It may be stated with confidence that nitrogen manuring is very beneficial to the alkaloid-forming plants, especially on soils containing a proportion of clay and lime; it is hardly possible for grow-

ers to over-manure on such soils with any nitrogenous fertiliser; growth of the plant is stimulated to a remarkable degree by such treatment, and in the case of *Atropa Belladonna* the rate of sprouting after cutting is also increased. Thus the crop obtained in any one season is increased very considerably as the result of treatment with nitrogen. Ammonium sulphate may produce damage and even a decrease of total yield if applied in high concentrations, though it increases alkaloid content in spite of this damage. Dressings at the rate of 1½ cwt. (about 160–170 lbs.) per acre are very beneficial to the crop. Other mineral fertilisers have very much less effect, but the usual balance between nitrogen, phosphorus, potassium and calcium produces the best results. The effect of calcium on *Atropa Belladonna* seems to be on the general growth of the plant and not at all on the alkaloid content.

Too heavy a dressing of the elements other than nitrogen, on the other hand, may have a deleterious effect, varying with the particular element and the particular plant in question. It seems quite clear that the best results are produced when there is a reasonable balance between the main nutrient elements, combined with a rich nitrogen supply.

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Utilization Abstracts

Charcoal. At the pilot plant of the Oregon Forest Products Laboratory experiments are being conducted on the carbonization of wood-waste in the form of headsaw sawdust and on the production of tarbound charcoal briquettes. The products are charcoal, tar, pyroligneous acid and gas. "All previous attempts in the establishment of a wood carbonization plant in the Pacific Northwest have been confronted by marketing problems".

Charcoal is needed for the industrial development of the region, especially in electrochemical and electro-metallurgical factories; in making carbon disulphide for viscose rayon manufacture and for seed fumigants, weed eradicators and rodent exterminators; in iron foundries, alloy steel foundries and carburizing ovens; also in poultry feeds and as a soil lightener. (*H. G. Rieck, Jr., E. G. Locke and E. Tower in The Timberman, reprinted in Chemurgic Digest 5(16): 273. 1946*).

Peanut Oil. Bulletin 247 of the Georgia Experiment Station, issued in 1946, discusses the stability of peanut oil and gives a comparison of peanut oil with other cooking oils.

Hawaiian Food Plants. "Foods used by Filipinos in Hawaii" is the title of Bulletin 98 of the University of Hawaii Agricultural Experiment Station, published in 1946. (*C. D. Miller, L. Louis and K. Yanazawa*).

Forest Products of Ecuador. During the recent World War the forests of Ecuador were the source of most of the world's supply of balsa, as well as of significant amounts of rubber, cinchona and kapok. With the exception of balsa [*Ochroma Lagopus*], little wood is exported. Though balsa grows also in Colombia, Brazil, Venezuela and parts of Central America, Ecuador has long supplied 90% of the commercial product; in 1942 and 1943 it was the principal forest export of the country, even surpassing Panama hats. Before 1941 balsa was used for making toys, movie sets, life preservers and insulation; since 1941 its uses have multiplied, and it became a strategic war material in the construction of Mosquito bombers, life preservers and rafts. Export of the material from Ecuador increased from an annual average of about 4½ million pounds in the 1936–1940 period to over 30 million pounds in 1943, since which time the quantity shipped abroad has dropped. About 90% of the war-time shipments came to the United States. Balsa trees grow 50 to 100 feet tall, but are ready for cutting when only two years old; the most economical cutting age, however, is between six and nine years. Nearly all the commercial supply is obtained from wild trees, but there is also some plantation balsa. The logs are floated down the rivers of Ecuador as rafts to the saw mills near the coast, where they are cut into lumber, and the latter either kiln-dried or sundried prior to shipment abroad.

Wild trees of *Castilla elastica* have long supplied small quantities of rubber for export, reaching a peak of 6½ million pounds in 1942, but the material has been classed as "scrap" in world markets. *Hevea brasiliensis*, the great rubber species of Brazil, is a potential source of commercial rubber in the country, and in 1941, through cooperation of the Ecuadorian and United States Governments, two hevea nurseries were established in which "thousands of trees have been produced from both imported and local seeds, and budded stumps and budwood of hevea trees have been imported and tested for adaptation to Ecuadorian conditions".

Cinchona bark is obtained mainly from two species of tree, *Cinchona officinalis* with gray bark and *C. succirubra* with red bark. The former is sent almost exclusively into Peru, while the latter is usually shipped abroad from Guayaquil. The bark of *C. officinalis* and of *C. pitayensis*, the latter found mainly in the eastern cordillera, is at present inaccessible because of inadequate transportation facilities. Most Ecuadorian cinchona bark comes from wild trees, but a few farmers have planted small acreages with the trees. Felling the trees usually begins in August; the bark is removed with machetes and dried over fires or in kilns. Under war-time demands exports of the bark rose from 207,000 pounds in 1942 to 7,000,000 pounds in 1944, all of it coming to the United States. Before the war Germany and Japan were the principal markets.

Tagua nuts, the seeds of a palm [*Phytelephas macrocarpa*], constitute one of the more important minor products of Ecuador. The nuts resemble ivory in hardness and durability, and have been important primarily in the manufacture of buttons, secondarily in that of novelty items, *e.g.*, chess men, dice, poker chips, umbrella handles and religious ornaments. Plastics are now competing strongly with the nuts in the making of these items. Wild trees are the sources of the nuts. The trees grow in jungle areas from Panama to Peru, but Ecuador is the center of production. As a result of demands for strategic materials during the recent war, exports of tagua nuts from Ecuador declined from 56¾ million pounds per year for 1935–1939 to 29½ million pounds in 1942.

Before the recent war Ecuador was second to the Netherlands East Indies, particularly Java, in the production of kapok fiber, extensively used as a filler in life preservers, mattresses, pillows and other items for which buoyancy, lightness and resistance to moisture absorption are important. Ninety percent of the supply formerly came from the Indies. The white fleecy fiber is the floss produced on the seeds of the ceiba tree [*Ceiba pentandra*] and is collected from trees along the coast. Secondary products of economic importance furnished by the tree include a medicinal gum from the trunk, a

rubber-like substance from the bark, edible oil from the seeds, and lumber. Exports have varied from 20,000 pounds in 1932 to over 1¼ million pounds in 1938.

The bark of mangrove trees (*Rhizophora* sp.), growing up to 150 feet tall in coastal sections of the country, is the principal source of tanning materials for use in the country itself. On the highlands a secondary source is a bark obtained on the paramos and known as "casca". More than 6½ million pounds of bark are extracted annually, and nearly 8 million more pounds used in local tanneries.

Panama hats, made from the leaves of the toquilla plant (*Carludovica palmata*), have long been a staple export item of Ecuador, reaching an estimated 4,400,000 hats in 1944, second only to rice in export value. Small amounts of the straw itself are also exported. "Toquilla straw comes from a small fan-shaped 'tree' without a trunk, which usually grows wild on the heavy fertile soils of the lowlands. The leaves grow to a length of from 5 to 7 feet and must be cut from the plant before they open. They are stripped of their outer filaments and the remaining fibers are dipped into boiling water, dried in the shade, and bleached in the sun before they are woven into hats. An average of approximately one-half pound of fiber is used for one hat. The making of the hats is a cottage industry, the quantity of fiber gathered and processed depending on the price for hats". (*Kathryn H. Wylie, Foreign Agriculture 10(5): 75. 1946*).

Origin of Cucurbits. The problem of the origin and subsequent domestication of the three annual cultivated species of *Cucurbita* (*C. Pepo* L., *C. moschata* Poir and *C. maxima* Duch.) has been reexamined, and a domesticated form of *C. Pepo* from southwestern United States described for the first time as distinct from others. The investigation endeavored "(*a*) to point out the essential differences between the three domesticated species; (*b*) to furnish evidence that there were at least two independent domestications of *Cucurbita Pepo;* (*c*) to show that these separate domestications produced distinct varietal types; (*d*) to correlate these findings with previous work so as to construct a theoretical picture of the relationships of the entities which exist within the domesticated cucurbits". (*T. W. Whitaker and G. F. Carter, Am. Jour. Bot. 33(1): 10. 1946*).

Brazil-nuts. Brazil-nuts [*Bertholletia excelsa*], known in Boston as "castanas" and in some parts of the southern United States as "nigger toes", are again among Brazilian imports into the United States after nearly four years of war-time absence. The former name, of Brazilian origin, was introduced by Yankee skippers of sailing ship days.

Brazil-nut trees grow almost exclusively in the upper reaches of the Amazon, and the nuts are floated down the river in barges to Manaos and then on to Belem, where they are graded and shipped to Europe and the United States. The trees grow 150 feet tall, preferably on high land far from the periodic overflow of the Amazon and its tributaries.

The nuts are borne within hard, spherical, thick-walled husks weighing two to four pounds, each shell enclosing numerous nuts. When the fruits ripen and fall they constitute a serious menace to the natives—"castanheiros"—who gather them.

Displacement of Brazil-nuts by minerals and other strategic materials in the exports from Brazil during the war meant a loss of about $15,000,000 so far as the traffic in those nuts was concerned. (*J. P. Lee, Brazil 20(6): 2. 1946*).

Japanese Mint. Japanese mint, *Mentha arvensis* var. *piperascens*, is the only practical commercial source of menthol, so extensively used in prescriptions, cold remedies, cough drops, dentifrices, mouth washes, cosmetics and tobacco. The plant is known also as "Japanese peppermint" and "hakka-maru", and is believed by some authorities to be a hybrid between *M. arvensis* and *M. aquatica*. It grows wild in nearly every bit of wet ground in Japan from Karafuto to Taiwan, and the two main producing regions within recent years have been the Province of Kitami on the Island of Hokkaido in northern Japan, where 70% to 80% of the Japanese mint oil is produced, and the District of Sam-bi in southwestern Japan, where 20% to 25% is produced. The leaves, stems and calyces of this perennial herb bear both glandular and non-glandular hairs, and the

menthol is dissolved in the volatile oil of the glandular heads on the hairs bearing them.

Prior to World War II production of mint oil and of menthol was one of Japan's principal chemical industries, and that country furnished most of the menthol used in the United States which consumes more than half of the world's annual production of about one million pounds.

The flavor of the oil of Japanese mint is inferior to that obtained from peppermint (*M. piperita*), but it has a higher menthol content—75% to 80% rather than 50% to 55%. This lower content of menthol in the oil of peppermint, costly and difficult extraction of it, and great demand with high prices for the oil itself, make it impractical to obtain natural menthol commercially from peppermint.

Rhizomes, cuttings from aerial runners, and stem cuttings are used for propagation purposes; seeds do not breed true. About 16000 cuttings are planted per acre. (*H. W. Youngken, Herbarist No. 12. 1946*).

Fats and Proteins from Cucurbits. In all parts of the world where squash is grown, except in the United States, the oil-containing seeds are relished as food and eaten as nuts. In the Balkan countries the oil of cultivated cucurbits is highly prized as a cooking fat, and in China watermelons are grown exclusively for their seeds.

The seeds of cucurbits are rich in fats and protein, and the three wild perennial species in southwestern United States, ranging from Missouri to California and south into Mexico, may offer sources of these essentials to the natives of those regions and to a fat- and protein-hungry world. Those three species, existing particularly in the desert, are *Cucurbita foetidissima, C. palmata* and *C. digitata*. The seeds of the last-mentioned were used as food by the American Indian.

Under cultivation these plants should produce approximately 1,500 pounds of seed per acre, about one-third of which weight would be attributable to the oil content and another third to the protein content.

In the Sahara Desert of eastern Morocco the author found a plant of *Citrullus Colocynthis* which occupied about 36 square feet of ground and produced 63 fruits, 25 of which contained exactly two pounds of seed. At that rate an acre supporting 1,210 plants six feet apart would produce roughly 6,000 pounds of seed.

In the seeds of perennial cucurbits there thus is a possibly great source of oil, not only for dietary use but also for manufacture of soap in such needy parts of the world as Mexico, Puerto Rico and North Africa. Nothing has yet been done about the matter, not even experimentally. (*L. C. Curtis, Chemurgic Digest 5(13): 221. 1946*).

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tea and the western hemisphere now furnishes 5/6 of the world's coffee. Brazil produces over half of this latter total, and Colombia is the largest producer of mild coffees. In value coffee is the chief export crop and constitutes a higher percentage of the total exports from Brazil (32%), Colombia (58%), Costa Rica (53%), El Salvador (76%), Guatemala (45%) and Haiti' (37%) than any other product. It ranks high in 14 of the 20 Latin American Republics.

In terms of plant geography it is interesting to note that ecological conditions of soil and climate have determined the areas of production more than any other factors. Tea, native of the Orient, has remained largely in its original and adjacent geographic homelands. Coffee, native of Africa and India, has been developed largely in the western hemisphere, especially in South America, where none of the 40 species originated. Of the estimated total of 5¼ billion cultivated coffee trees in the world, over four billion are in South America. Cacao, native of North America, reaches its maximum production in the Gold Coast of Africa.

The flavor characteristics of the commercial types of all these beverage sources are due, to a great degree, to the ecological combinations under which they are grown. Tea-testers can recognize the source of tea with amazing accuracy; and lowland and highland grown coffees also readily reveal their identity by the body, acidity and flavor of the cup beverage. Production of maté and guaraná has remained in their native habitat of Brazil and adjacent territory. Yerba matte has a "strong" or "mild" flavor, according to the soil composition and atmospheric conditions under which it is produced. It is obvious, therefore, that plant geography, agricultural phases of botanical science and the effect of these beverages upon the physical health of the consumers, together with the problems of international economy, form a complex network of major importance to the well-being of the world's populations.

Tea

Production and Consumption. For 16 centuries tea drinking has been on the increase until world production today is annually two billion pounds. It is still cultivated largely in its original geographic distribution in the Orient. China is the No. 1 producer, but India is the No. 1 exporter and the No. 2 producer. Ceylon is No. 3 in tea crop production but No. 2 as a source of U. S. tea. U. S. imports have reached nearly 100 million pounds annually (98,962,516 lbs. in 1940 and 83,814,569 in 1945). In 1946 tea inventories in the U. S. were six to eight million pounds (9/10 Black and 1/10 Green tea) higher than for any pre-war year. Tea is so important to the American palates of the U. S. that in 1943 the Federal government took charge of the importation of it as a war measure and received a quota ration from Ceylon under the British-American allocation agreement. We consume over one million pounds per week, and in 1940 we paid over $20,000,000 for the 99 million pounds imported. In addition to the major production areas of China, India, Ceylon, the Netherland Indies and Japan, tea is now grown on smaller acreages in the Union of South Africa which supplies itself with only 1/20 of its requirements, in British India, British Malaya, Southern Rhodesia, Kenya, Uganda, Mauritius and Nyasaland.

Tea is also cultivated in Brazil, Russia, Natal and Guatemala. About a century ago in the United States tea as a crop was tried successfully from the agricultural standpoint but failed economically. Brazil has grown some for over a hundred years. Brazilian tea represents hybrid types of Indian (Assam) and Chinese varieties. Eight firms in that country trade in the production from

FIG. 2, (*Upper*). Mr. George F. Mitchell, left, and Mr. Raymond B. Partridge, right, in the tea-testing laboratory of the General Foods Corporation, Maxwell House Tea Division. FIG. 3 (*Lower*). Chart showing the relative consumption of tea during the day by men and women in Great Britain, a great tea-drinking nation. (*Chart by V. Puglisi, courtesy Time Magazine.*)

two million tea plants yielding over 50,000 kilos of finished tea, and the largest tea plantation in Brazil is "Fazenda do Tesoureiro". Brazilian tea has a high tannin content (15.4%) which is desirable because good tea leaves contain over 30% water-soluble substances, and a high tannin content gives body. Brazilian tea types are the equivalent of Broken Orange Pekoe, Orange Pekoe, Pekoe and Broken tea, consisting of first leaves and bud, second leaves, third leaves and a mixture of broken leaves of types of the first three types, respectively. Brazilian tea exports are increasing, as indicated by 71,776 kilos in 1939, 91,507 kilos in 1940, and 134,163 kilos in 1941. During World War II tea became a naturalized citizen of Guatemala where commercial plantations have been developed in a favorable soil and climate environment, and there is the possibility of great expansion in that area if the need arises.

History. A probable origin of tea as a beverage is, according to legend, due to the experience of a Chinese philosopher who was using twigs from a tea bush (tree) as firewood. Some of the leaves fell into the pot of boiling water and sent up a delicious aroma. He tried the brew and enjoyed it, and tea as a beverage was born. The Dutch brought tea to Europe in 1610. It was introduced into England by 1664, and today London is the tea capital of the world, importing 450 million pounds annually. In 1690 Benjamin Harris and Daniel Vernon were licensed there to sell "Coffee, Tee and Chucaletto". The relative number of cups of tea consumed by the average man and woman of Britain between 7 A.M. and midnight shows early morning and late afternoon-early evening to be the great tea hours of this tea-drinking nation where the average person drinks five cups a day (Fig. 3).

Tea was first advertised for sale in Boston in 1714, and in 1728 it was offered to the New York public. When tea was first used in Salem, Massachusetts, it was boiled in an iron kettle, the liquor drained off and the leaves eaten with butter and salt; the infusion was also consumed as a beverage. This early practise was somewhat like the eating, as well as drinking, of tea in Mongolia today where the Chinese women press tea leaves into solid blocks for export by camel caravan to the interior of Mongolia. This Brick tea is an important staple in the Mongolian diet, and is stewed in water until softened and then eaten with butter or with tsamba which is ground and parched wheat or barley. Today the U. S. is a Black tea (fermented type) drinking nation, consuming annually 68,000,000 pounds of Black tea, compared with 20,000,000 pounds of Green (unfermented) tea and only 6,000,000 pounds of Oolong (semi-fermented) tea for which the leaves are only withered and oxidized slightly before they are panned (steamed) to stop the fermentation process.

Cultivation and Harvesting. Tea is derived from the leaves of *Thea sinensis* (L.) Sims (= *Camellia sinensis* (L.) O. Ktze.), and only the bud and the first two young leaves at the end of each twig are really desirable, although the third and even the fourth leaves are used in inferior qualities. This is in sharp contrast with deliberate preference for the fully mature leaves in the harvesting of yerba maté, the popular native tea in South America.

Tea trees are grown from seed, but commercial plants are kept pruned to bush size for convenience in harvesting. Some are allowed to grow to their full natural height of 15 to 20 feet and to bear fruit, thus serving as seed trees. Seedlings remain in the nursery for a year, and after having been planted out, a first plucking occurs which is a light picking and nonprofitable. The first commercially advantageous "flushing" (complete picking) is at the end of five

years. The plants are pruned slightly annually, then drastically during the early Spring of the third year and finally collar-pruned (cut almost to the ground) when ten years old. This results in

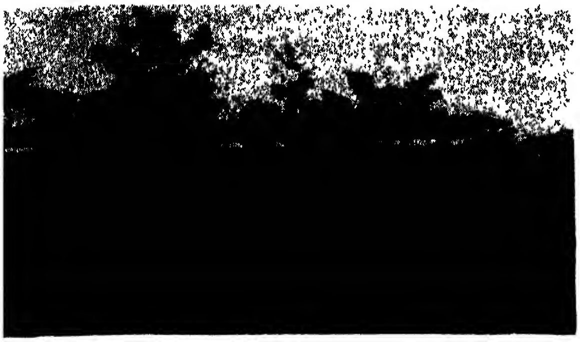
FIG. 4. The flowers, terminal leaves and bud on a twig of a tea bush. (*Courtesy The New York Botanical Garden.*)

suckers growing up from below ground to produce a very large tea bush with several main stems. Such a plant yields a tea crop approximately every 40 days for years in a good growing area. The world's largest tea "bush" is 24 feet in diameter and 67 feet in circumference. It is on the Battawatte Tea Estates in Ceylon.

The native pickers cleverly pluck the terminal bud and the first two leaves of all the twigs on a bush, tossing them over their shoulder into a basket. If the third leaf is tender and desirable, the plucker breaks it off at the same time. The basket hangs by a strap around the head, and if a baby is brought along, the child is supported by the shoulder strap so that both of the mother's hands are free for picking.

In Japan white jasmine flowers, called "Mokle", are added to the pickings to flavor the tea and gives us the commercial "Jasmine Tea".

Processing. After plucking, tea leaves for Black tea (fermented) are spread on withering racks (chungs) for 12 hours to allow the proper degree of oxidation. They are then rolled by hand or machine to break the cells without tearing the leaves. Further oxidizing and desired fermentation are allowed until the leaves assume a copper color when spread out on tile or cement floors or tables. Firing (drying) is accomplished in baskets over charcoal fires or in tea-firing machines in modern factories. The largest tea factory in the world is on the east coast of Sumatra at Balimbingan. Leaves for Green tea (unfermented) are panned (steamed) soon after plucking to stop fermentation. In Ceylon and India freshly plucked leaves are steamed in revolving perforated cylinders. In China, Japan and Formosa, where hand manufacture is more common, the leaves are tossed about by hand in an iron vessel built into a charcoal stove. As soon as they become soft, they are removed steaming hot and rolled by hand on a bamboo mat or a paper tray. Leaves are returned to the



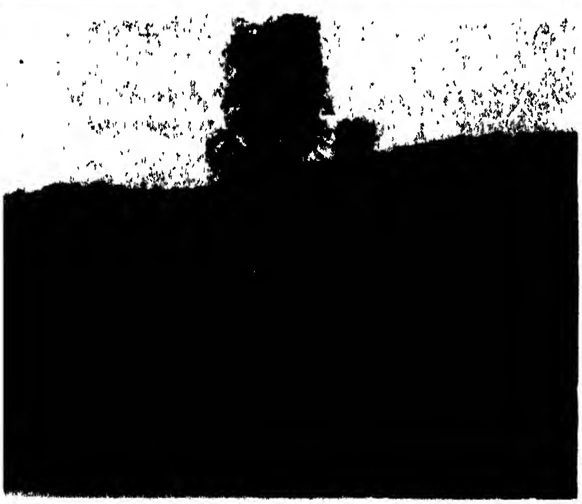
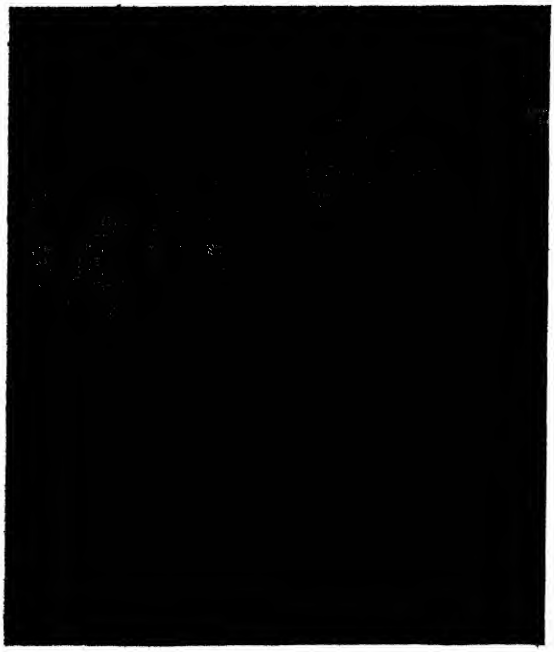


FIG. 5 (*Upper left*). Withering racks, or "chungs", for the manufacture of Black tea in Assam. FIG. 6 (*Upper right*). Ceylon tea baskets and pickers sorting out the tough third and fourth leaves from a poorly picked crop. FIG. 7 (*Center left*). Clearing the forest for tea planting. FIG. 8 (*Center right*). A tea nursery. FIG. 9 (*Lower left*). Drastic third-year pruning of tea bushes; the tall plants are unpruned tea bushes left to serve as seed trees. FIG. 10 (*Lower right*). Tea factory on a tea estate in Ceylon; the tall trees are legumes planted among the tea bushes to enrich the soil. (*Photos courtesy G. F. Mitchell.*)



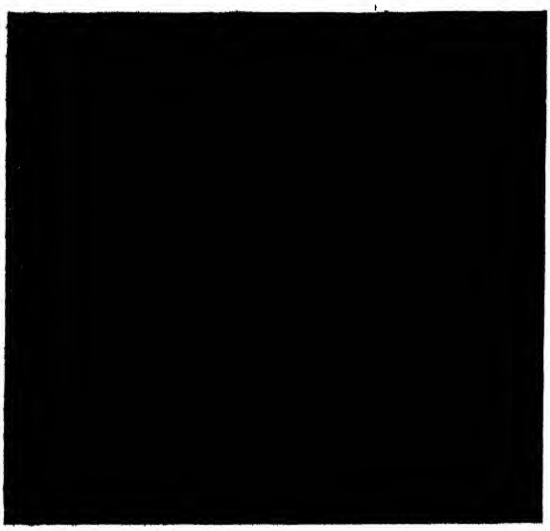


FIG. 11 (*Upper*). Tea pickers of Darjeeling, India, sometimes wear shade hats to prevent premature withering of the leaves in gathering them for Green tea. FIG. 12 (*Lower*). A Ceylon tea bush as plucked or "flushed" several years for commerce, displaying many twigs from which the terminal bud and first two leaves have been picked, and which will develop new tips and be ready for plucking again in approximately 40 days. Against the card are shown a bud and the first two leaves of the twig, which are harvested every 40 days or so, as well as the third leaf which may be crushed off without injuring its axillary bud if the leaf is still tender. (*Courtesy G. F. Mitchell.*)

pan again in a few minutes, and the rolling and steaming processes are alternated until the leaves begin to crisp. They are then put into trays and dried thoroughly over slow charcoal fires.

Kinds of Tea. Harvesting the terminal buds and the adjacent two leaves together is called "fine plucking" and constitutes the finest tea. Including the third leaf is "medium plucking", and inclusion of the fourth leaf is "coarse plucking". Black tea is fermented, Green tea is unfermented, and Oolong tea is semi-fermented. "Pekoe" is Chinese for "white hair" and originally meant the earliest pickings of tea leaves covered with the young "down". "Pekoe" and "Orange Pekoe" were applied originally in China to tea scented with orange flowers. In general today, however, Orange Pekoe is a grade which results from sifting tea, after firing, through a sieve which has a mesh of a certain size. The term "Orange Pekoe" is in no sense a description of quality. The grade Pekoe is a lower leaf grade than Orange Pekoe, both of which result from sifting.

The principal kinds of Indian Tea in northern India are Assams, Darjeelings and Dooars. In Ceylon the types are High, Medium and Low-grown teas. In China the tea classification is China greens, China blacks (congous), Oolongs, scented and compressed. The three leading varieties of north China are Blacks (Keemuns, Ningchows and Ichangs), Burgundies and South China Blacks (including the Congous, red leaf Congous, Kaisows and Foochow Congous). The Clarets are Chinese. Netherland Indies teas are black teas known as "Java" and "Sumatra" together with the special identifying mark of the tea gardens in which they are grown.

Tea Tasters. Professional tea-tasters develop an amazing ability to identify the country and district of origin and

even the season of picking. Tasters sip and sip but rarely swallow. We of the United States depend upon the acuity of the specialized taste sense of less than 40 men as our guide to new fragrant blends and for the wise purchasing and blending of the leaves to maintain the uniformity of the commercial brands enjoyed by the general consumer.

Coffee

General. Coffee appeals to the human senses from its flowering stage to the aroma and flavor of the cup beverage. Its abundant and small but fragrant white blossoms, occurring in clusters and covering the small trees from six to 30 feet tall, delight the eye and perfume the air during the few days of bloom. Flowers occur once a year in dry areas but several times a year where rainfall is plentiful up to 70 inches annually. In such a climate, blossoms and green fruit, with some of the latter ripening to red and reddish black, may all occur on the tree at the same time. If the rainfall is less than 30 inches annually, irrigation is mandatory. The succulent pulp of the ripe "cherry" is sometimes eaten by the pickers. The fruit requires seven to eight months to mature and contains two seeds (beans) within the pulp, each of them possessing a parchment covering within which is the delicate but tenacious silverskin. Pulp, parchment and the silver-colored, tissue-paper-like "skin" must all be removed before roasting.

The coffee belt reaches from 20° below to 20° above the equator and extends around the world from sea level to between 5,000 and 6,000 feet elevation. Coffee flourishes best and produces the highest quality beans at about 4,500 feet, although excellent coffee is obtained at higher altitudes also, provided its great enemies, frost and drought, do not interfere. Coffee prefers a fertile soil rich in potash, and many plantations are located on volcanic hillsides and tablelands. Nursery stocks are grown from selected seeds. A coffee plant produces fruit first during its third or fourth year. Plants are pruned in the second or third year to facilitate picking and increase yield in later years. From the fifth to eighth year, when the plant reaches full maturity, to the 15th year, each tree yields one to eight, or occasionally 12, pounds of beans. The yield depends largely upon climatic conditions, and record trees have produced 17 pounds in one year. Some trees bear profitable crops up to 30 years and will produce somewhat up to 100 years. Typically, however, the trees are cut to the ground when their yield ceases to be profitable. A new tree then grows from a hardy sprout of each stock, or new nursery material is planted.

Harvesting and Processing. Climatic conditions also regulate the harvesting method. If all fruits ripen at the same time, as in relatively dry areas, they may be stripped off, but in regions where rainfall and temperature (averaging 70° F.) are more evenly distributed throughout the calendar year, the ripe fruits must be selected individually. This requires picking with greater care and over a longer harvesting period. The weather controls the time and uniformity of fruit maturity and so determines the picking season between May and September under the Brazilian climate. There is only one main harvesting season a year. Coffee picking must be accomplished when the cherries are ripe because they soon become shrivelled. Everyone—men, women and children—all take part in the harvest.

Tossing coffee cherries into the air removes more of the leaves and sticks than does sifting. After freshly picked fruits have been freed from debris, by either sifting or winnowing, they are "cured" by the dry or wet method, depending primarily upon the availability

of water. Wet-prepared, *i.e.*, washed coffees, are preferred by the market, but, because of scarcity of water during the picking season, the dry method is practiced with most Brazilian coffee and in the drier areas of other countries.

In the dry method, the "cherries", as the bean-containing fruits are known, are sun-dried in thin layers on flats, usually concrete areas, where they are raked over several times a day for three weeks. The dried fruits are then depulped and hulled (parchment removed), and the silverskin rubbed off, all in one general process by threshing or pounding in mortars on small plantations, or by special machines on the large fazendas. The machine which accomplishes removal of all three layers in one process during this dry treatment is a different type from the depulping (only) machine used in the wet method. The beans are then graded or sized automatically by machine and bagged for warehouse storage.

In the wet method the "cherries" are soaked overnight in large tanks and conveyed in water to mills where the pulp is removed readily the next morning by friction in a depulping machine. The slimy beans are next fermented in tanks to remove adhering traces of the saccharine pulp which is then washed away in vats. The value of this fermentation factor, which is greater in the wet method, is debatable regarding its effect upon the quality of the cup beverage.

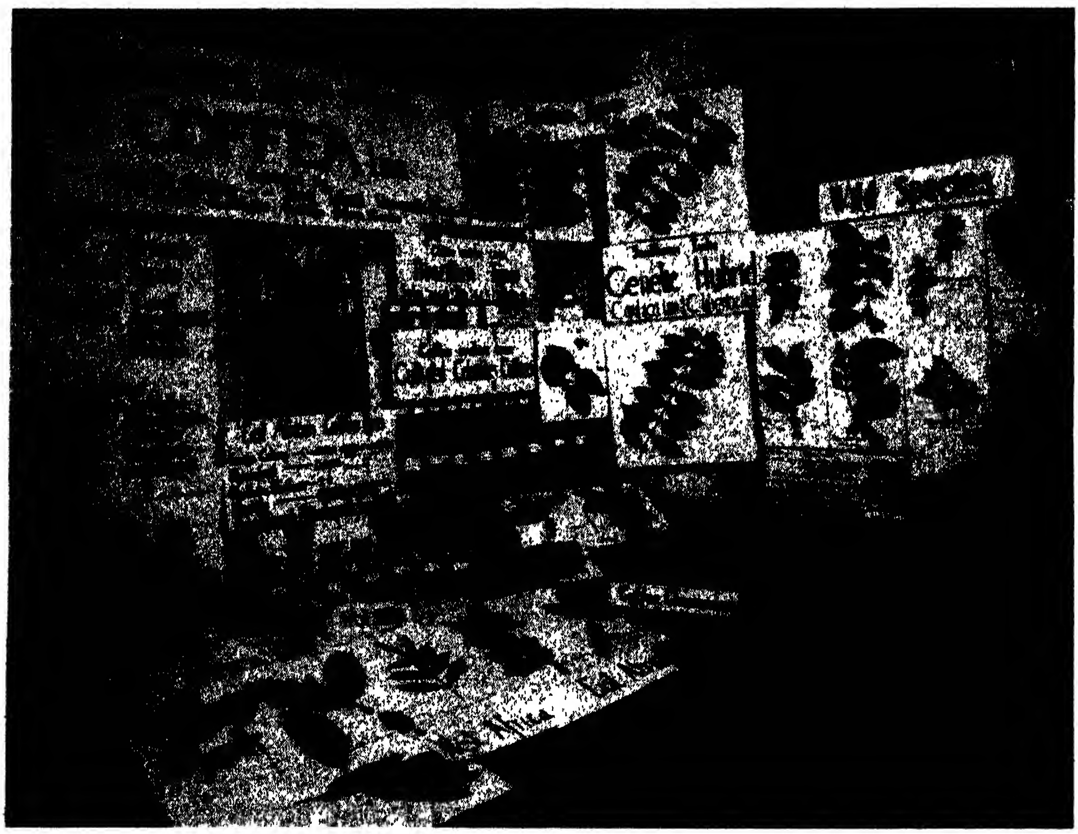


FIG. 13. Coffee exhibit arranged by the author at the Sixth International Congress of Genetics at Cornell University in 1932.

As a result of this preliminary wet

method treatment the depulped "washed" coffees are clean, parchment-enclosed beans. They are next spread on concrete drying grounds for ten days with roof-like coverings on wheels to protect them against rain or the daily dew and to complete the final stages of the drying process under shade. Drying by hot-air driers in buildings gives better control and reduces the entire drying process to 24 hours. After drying, the desiccated thin parchment is peeled off and the silverskin polished off in one friction process by passing the beans between a revolving cylinder and an outer

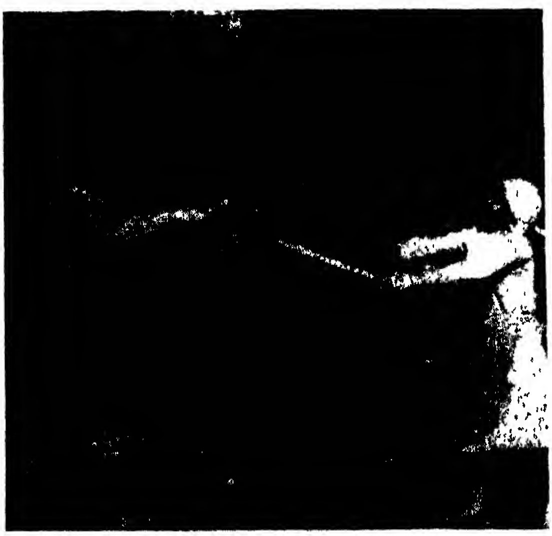


FIG. 14 (*Left*). Winnowing freshly picked coffee in Brazil to remove leaves, sticks and other debris. FIG. 15 (*Right*). A Brazilian girl eating freshly picked coffee "cherries". (*Courtesy Brazilian Government Trade Bureau, N.Y.C.*)

wire mesh with air blasting to eliminate dust and bits of silverskin. Grading or sizing of the cleaned beans is then performed by machine sorters; and finally, faulty and discolored beans are removed by hand. Coffee beans are packed in 60 kilogram (132 lbs.) bags for storage in warehouses, and the Serviço Téchnico of Rio de Janeiro lists eight grades for Brazilian coffee: No. 1 allows no imperfections per pound; No. 2 allows four imperfections; No. 3 allows 12; No. 4 allows 26; No. 5 allows 46; No. 6 allows 86; No. 7 allows 160; No. 8 allows 360. They are all generally referred to as either "Santos" or "Rio", according to the general area of production and port of shipment. The best Santos is known to the trade as "Bourbon". Most Colombian coffee is washed, and the finest type is grown in the Medellin region and known commercially as the "Medellins".

Unroasted coffee of the trade is known as "green" coffee. Trade classification involves not only imperfections in general but the specific physical appearance of the bean such as size, form, texture, color; and chemical characteristics of the beverage such as astringency, bitterness, dryness, harshness, mellowness, mildness, neutrality, acidity, pungency and rank. The beverage is described as being "strictly soft" (very mild and sweet), "soft" (mild and sweet), "hard" (harsh) or "Rio" (harsh and bitter). The two main trade categories are "Brazils" (strong and pungent) and "Milds" (mostly from other countries than Brazil). The best coffees for beverage utilization are blends. Green coffee has no palatable flavor. Heating to 300° F. begins to cause chemical changes. At 350° F. the beans turn yellow and aroma

begins. At 375 to 400° F. the brown color appears and the beans crackle due to the rupturing of the seed structure. Exact temperatures, roasting time and blending are trade secrets. The U. S. population prefers a medium roast obtained in approximately 15 minutes or somewhat longer. Commercial roasting at 1,000° F. by passing hot gases through beans in a perforated, revolving cylinder, creates an aroma and flavor by developing an aromatic oil, caffeol. This oil is highly volatile and the bean deteriorates from the moment it is roasted. For a period of a few days the rate of deterioration is relatively rapid, then much slower over a longer period. Very stale coffee is unpalatable and has changed

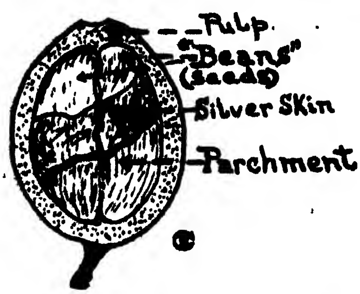


FIG. 16. Vertical section of a coffee fruit or "cherry", twice natural size, showing the location of the deep crimson skin surrounding a yellowish pulp within which, invested first by a delicate "silver skin" and then by a cartilaginous "parchment", are the two coffee beans, or seeds.

chemically which does not improve its physiological effects. Roasting not only develops the aroma and chief flavoring compounds in the bean but it caramelizes its sugar, carbonizes its cellulose and lignin, reduces its weight 20% and increases its volume 30%.

Species. Coffee is derived from about 40 species of the genus *Coffea* L., but cultivated coffee is obtained largely from only three species, *viz., C. arabica* L., *C. liberica* Bull. and *C. robusta* Linden. Within and between these species there are varieties and hybrids which, along with many other details of botanical, chemical, economic, social, literary and historical aspects, can not be discussed here because of limited space. Amplification of these phases is to be found in two volumes on the subject, one by the present author under the title "Coffee", the other by Wm. Ukers and known as "All About Coffee".

Economics. No other household beverage has had more opposition to its use than coffee, despite which it today enjoys the most wide-spread popularity of all beverages. It has been substituted for, and adulterated with, the products of other plants from 38 families involving 98 genera and 213 species. Tulip bulb "coffee" sold in Holland during World War II for $35.00 a pound on the black market, but those unhappy days are over and pure coffee is again available there. On the U. S. market, with the exception of labelled cereal substitutes, all coffee is pure coffee. A small percentage of chicory root is added in some localities, especially in the South, as preferred by public taste rather than as an adulterant. However, it was estimated in 1938 that in the world-at-large, especially in parts of Europe and including the U. S. cereal coffees named above, the quantity of imitation and adulterated coffee still drunk annually was equivalent to 10,000,000 bags of 60 kilos each.

A century and a quarter ago coffee was imported as a luxury. Today it is our pleasing and stimulating national drink. Pound for pound, tea contains more caffeine, but the coffee cup beverage has two to three times the caffeine content of a cup of tea. Our American soldiers in 1942 drank 6,000,000 cups a day, and U. S. consumption in 1946 was 2½ billion pounds—an all time record. Coffee leads the import parade of food products in tonnage (140 million tons annually) and is followed in order by sugar, fruits, fish, chocolate, tea, fancy vegetables, spices and cheese. Brazil supplies one-half the coffee demand of

the world, and the U. S. takes one-half of Brazil's production. Up to 1914 Europe was the largest market for Brazilian coffee, but since then the U. S. is Brazil's best customer. A potent factor in our "good neighbor" policy with Latin-American countries is the coffee bean because so much of their prosperity depends upon the average American's desire and ability to consume nearly 550 cups a year.

World Production. Coffee is actually cultivated in 90 geo-political areas of the world, involving 31 countries of the Americas, 14 in Asia, 9 in Oceania (Melanesia, Australia, Micronesia, Polinesia) and 36 in Africa. Production quantities give coffee a place of major importance in the economy of 40 of these countries. Of the 5⅓ billion coffee trees under cultivation in the world in 1943, over four billion were in South America and covered 8,658,076 acres. Of these four billion, Brazil had 2,790,302,700 distributed in 14 States, of which 1,482,-183,300 were on the 70,000 coffee estates in São Paulo.

The world distribution of coffee trees geographically in 1943 was:

South America	4,030,640,700	trees
Central America	364,718,000	"
North America (Mexico)	133,606,000	"
West Indies	259,735,000	"
Africa	205,600,000	"
Asia	40,000,000	"
Oceania	292,500,000	"
World Total	5,326,799,700	trees

In spite of its great popularity, conditions arose a few years ago which resulted in over-production. This caused the elimination by incineration in Brazil of 77,070,577 bags of 60 kilos (132 lbs.) each, during the 12-year period of 1931–1943. The most drastic years were in 1933 when over 13½ million bags were burned and in 1937 when the total reached over 17 million bags. World production has decreased steadily since 1936, and together with control methods and the development of new uses for the by-products of coffee, such as the plastic, Cafelite, it is hoped that over-production will cease to be a major problem.

Although Ethiopia and Arabia, Africa and India are the original homelands of the coffee species, the major cultivation today is in South America. The following table indicates the geographic source of our U. S. coffee imports as shown by statistics for the years 1940 and 1945. The total in 1940 was 2,055,050,138 lbs. valued at $126,768,444, and in 1945 it reached 2,716,479,896 lbs. valued at $345,749,262. Green beans were imported from 28 different geographic areas, and a small quantity of roasted beans from a few non-producing countries such as Canada, Italy and Portugal, bringing the total to 31 sources of coffee importation into the U. S.

FIG. 17. A coffee tree bearing fruit in the greenhouse of The New York Botanical Garden. (*Courtesy The New York Botanical Garden.*)

Chocolate and Cocoa

General. Chocolate, the most nutritious of all beverages, originated from

UNITED STATES COFFEE IMPORTS

Source	Year 1940 Pounds Raw or Green*		Year 1945 Pounds Raw or Green†
Aden, Arabia	333,011		220
Belgian Congo	6,813,585		677,278
Brazil	1,099,141,968		1,547,321,616
British East Africa	4,534,836		0
Colombia	530,023,536		601,972,779
Costa Rica	16,168,331		44,648,794
Cuba	8,290,455		1,555,865
Curaçao	19,397		0
Dominican Republic	10,508,186		34,522,531
Ecuador	27,083,304		16,008,222
El Salvador	97,309,005		120,570,196
Ethiopia	93,702		0
Guatemala	80,319,349		105,282,737
Haiti	19,047,399		61,943,761
Honduras	2,241,899		5,871,995
Jamaica	108,379		0
Mexico	52,618,854		73,142,052
Netherlands Indies	13,047,763		0
Nicaragua	30,110,600		27,208,835
Other British West Indies	16,500	(Liberia)	1,120
Other Portuguese Africa	5,422,520		5,731,783
Panama Canal Zone	460,217		644,355
Panama, Republic of	32,682		0
Peru	1,294,967		4,248,162
Saudi Arabia	3,938,638	(Sudan)	2,204,607
Surinam	459,945		0
Trinidad and Tobago	39,200		1,095,500
Venezuela	45,571,830		61,827,488
Total	2,055,050,138 lbs.		2,716,479,896 lbs.
Value	$ 126,768,444		$ 345,749,262

* A total of 14,513 pounds was imported also in 1940 in the roasted or processed state from Canada (515 lbs.), Cuba (59 lbs.), Italy (2,354 lbs.), Mexico (6,735 lbs.) and Portugal (4,850 lbs.), totalling a value of $2,114.

† A total of 610,815 pounds valued at $85,706 was imported in 1945 in the roasted or processed state from Canada (11 lbs.), Brazil (500 lbs.) and the Dominican Republic (610,304 lbs.).

a tropical American plant distributed in the mountain valleys of Mexico, Central and South America. The Mexican Indians called the beverage "chocolatl" from their word "choco", meaning foam, and "atl" for water. *Theobroma Cacao* L., its scientific name, means "food for the gods". The Aztec Emperor Montezuma would drink no other beverage from the golden ceremonial goblets. Columbus took cacao beans back to Spain, the first European country to use them. The beverage became popular only after addition of vanilla, which is also native to Mexico, became customary. There has never been a substitute for the cacao bean which gives us the liquid chocolate, cocoa which is chocolate powder with the fat mostly removed, and cocoa butter used in pharmaceutical and toilet preparations and in the manufacture of candy, beverages and foods.

The stimulating agent theobromine in cacao beans is related chemically to caffeine into which it is converted in considerable quantities by methylation. Factories have been built at São Paulo for that purpose. Unlike tea and coffee, chocolate is a real food; but like them, drinking the beverage has been a custom

for centuries and has served as a symbol of welcome and often has other social implications. The common use of chocolate at Latin-American wedding receptions originated in early Honduran Indian ceremonials. A young man would send a girl a gift of enough cacao for a celebration, and if the offering was accepted, a party followed. Then if he was in favor, the girl presented him with cacao for two parties, one to be held at his home and the other in the home of her relatives. To ask a young person bluntly in some Latin-American countries today—"When are you serving chocolate?"—implies the question—"When are you to be married?"

Cacao beans were first brought into the United States for the manufacture of chocolate by Gloucester fishermen who accepted them as money for goods exchanged in tropical America. The original mill in 1765 was in Dorchester, Massachusetts. By 1790 over 500,000 pounds were imported annually into the U. S.; in 1900 the amount brought in reached 20,000,000 pounds; today it is about 680,000,000 pounds, and chocolate is the No. 1 flavor of the country.

The Plant. The cacao plant attains a height of 40 feet in its native state as it grows in the Amazon basin of Brazil, the Orinoco river area of Venezuela and the coastal valleys of Central America. For cultivation it is kept pruned to 15 to 25 feet. It bears large red and green, glossy leaves, and its small, inconspicuous flowers and large fruits grow in a very unusual manner, appearing along the main trunk and large branches. The fruits have leathery, semi-woody rinds, and resemble small, elongated melons in size, passing through several color changes as they ripen. In matur-

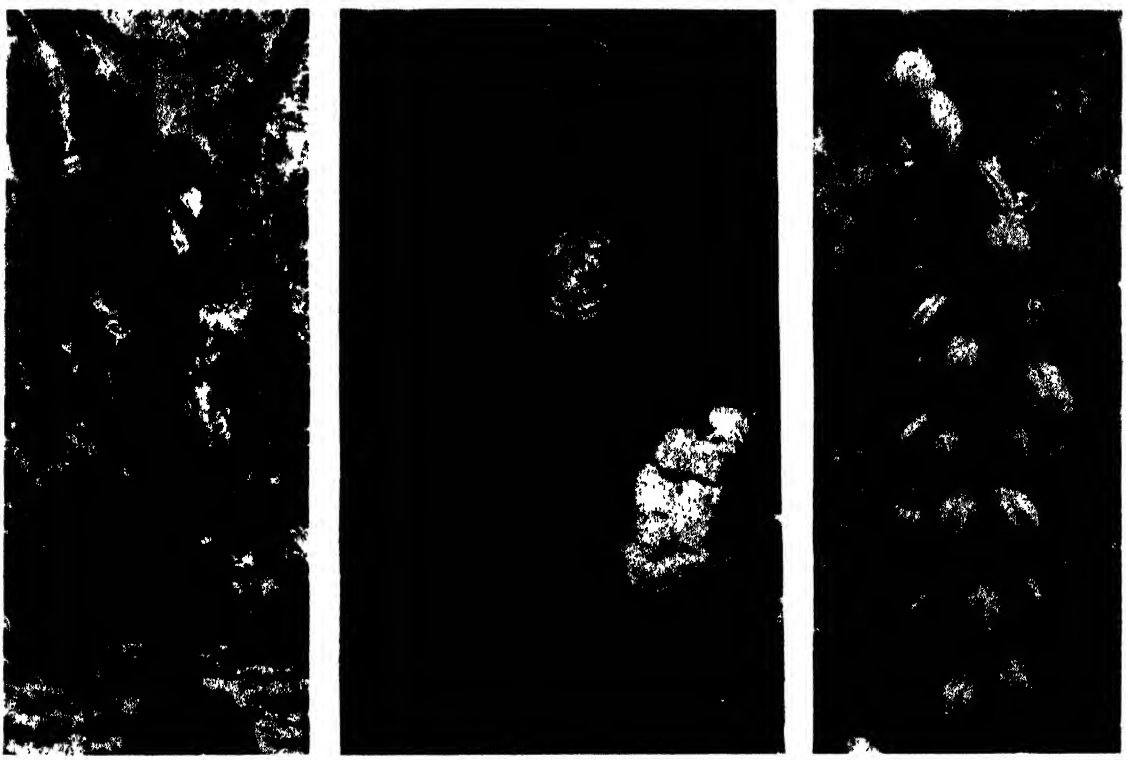


FIG. 18 (*Left*). Criollo type of cacao pod, the best for flavor. FIG. 19 (*Center*). Forestero type of cacao, the source of most commercial cocoa. FIG. 20 (*Right*). Calabacillo type of cacao, the poorest in flavor but fairly resistant to the pod disease. (*Courtesy La Hacienda.*)

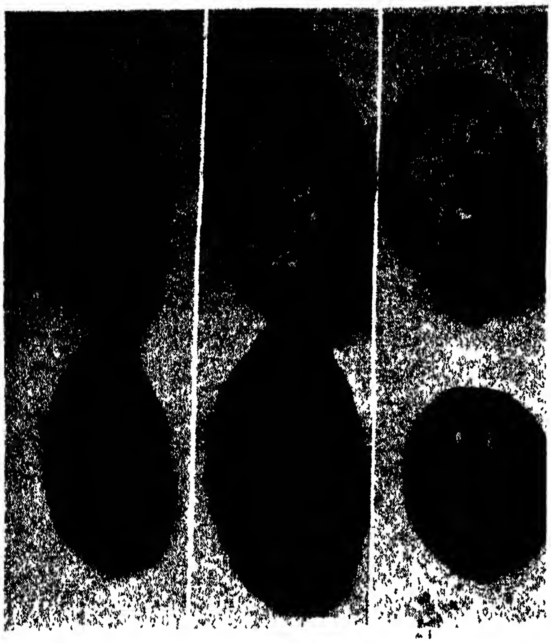


Fig. 21. Longitudinal cross-section and surface views of the three types of cacao pod; Criollo, left; Forestero, center; Calabacillo, right. (*Courtesy Pan American Union.*)

ing, the red variety turns carmine to vermilion to orange or reddish-brown, whereas the yellow variety changes from green to yellow. The impression gained by looking through a cacao plantation of mixed varieties has been likened to the effect of trees hung with Chinese lanterns. The fruits require four months to ripen, and each contains 20 to 50 almond-shaped seeds or beans embedded in a soft pulp. Each seed is enclosed in a parchment shell containing two oil lobes.

Cultivation. As is true also of tea and coffee, the quality of cacao beans depends not only on the variety but also upon the properties of the soil and climate; and upon the care exercised in controlling the curing and processing treatment. Cacao plants require a rich but well-drained soil and are so sensitive to drought and altitude that they seldom grow above 2,500 feet. They are always cultivated for the first two to four years under the shade of other trees such as banana, breadfruit, mango or rubber. Irregular rainfalls are responsible for oscillations in the volume of crops. The seeds are selected from high-yielding trees and are sometimes grown in bamboo joints or in palm leaf baskets until transferred, basket and all, to the plantation field. The tree produces fruit naturally in three years, but under cultivation, flower buds are destroyed until the fifth year. Full productivity occurs by the eighth year, and the trees continue to bear for 30 to 80 years.

With the continuous growing conditions of the tropics, flowers and pods may occur on the trees at all seasons, but there are usually two periods when many ripen at one time. This time varies in the different producing countries, but the heaviest arrivals on the world markets are in October and February. Smaller shipments are made in midsummer or early autumn.

Harvesting. Since unripe fruit gives

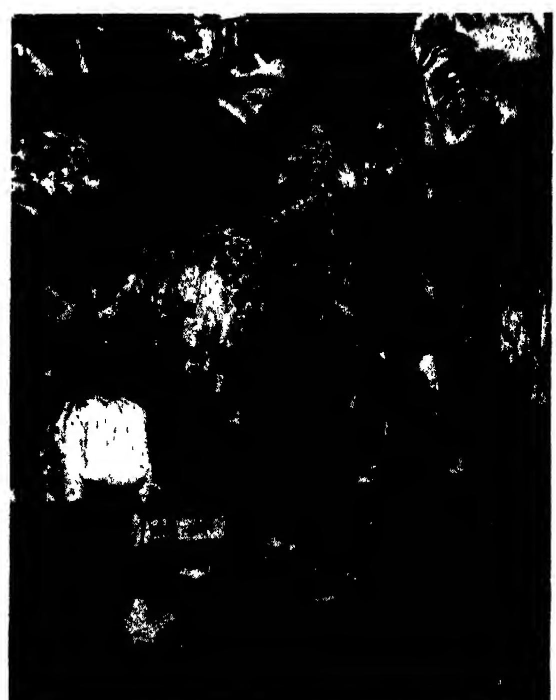


Fig. 22. A young cacao plant growing in the shade of large banana trees. (*Courtesy The New York Botanical Garden.*)

cacao of inferior quality and hinders fermentation changes, careful picking of mature fruit only is essential. There is an interesting division of labor between men and women during the harvest. First, skilled male pickers (tumbadores), trained in judging ripeness by the outer appearance, cut the fruit from the tree by means of mitten-shaped knives at the end of long poles. Native women fill baskets with the pods, carry them to a clearing and pile them on the ground. Opening of the multi-colored fruit is done by men who split them with a long knife by two to four blows, depending on the expertness of the laborer (peon). An expert worker can split open 500 pods an hour. Then girls separate the cacao beans from the pulp and lay them on banana leaves or trays for fermentation. Fermentation by the bean's own enzymes and by wild yeast of the air goes on for two to nine days. The wet beans are then exposed to the sun by spreading them out on concrete drying grounds for several days until dry to avoid molding, and after being graded and bagged they are stored in warehouses.

Processing. In the manufacturing process of chocolate and cocoa, the beans are "sieved" by being passed through rotating screens which remove the parchment covering (shell) and other extraneous matter. Both shells and nibs have some theobromine content. Uniform roasting of cleaned beans is accomplished in revolving drums. Crisp roasted beans are subjected to a machine which breaks them up, fans out parchment shell fragments and separates the broken beans, or nibs, into different sizes by passing them over a series of sieves. These roasted nibs contain 50% fat which is extracted and known as "cocoa butter". This butter is very useful because of its two valuable properties of freedom from rancidity and its blandness. Milling (crushing) of the nibs between grinding stones produces a thick plastic chocolate liquor which solidifies upon cooling and forms the bitter chocolate. Cocoa is the sifted powdered press cake after most of the butter (fat) has been removed from the chocolate liquor by hydraulic pressure. Cocoa possesses only 18% fat. The cacao mass to be used for various chocolate purposes is refined by additional grindings to form a smoother paste, sweetened with sugar and finally flavored with vanilla to make sweet chocolate. Powdered milk is added for milk chocolate. Extra cocoa butter is added when the chocolate is designed as a coating for bonbons. The chocolate paste is placed in a warm compartment, mixed well and deposited into the moulds of familiar commercial forms. In the manufacture of cocoa, besides reducing the fat content to 18%, sometimes sugar and dried milk are added to the sifted cocoa powder. For Dutch type cocoa the powder is treated with alkali to produce a darker color and a slightly different flavor.

FIG. 23. Young cacao plants growing in the partial shade of castilloa trees. (*Courtesy The New York Botanical Garden.*)

Types. There are three main types of cacao, and a pure plantation of any one type is rare:

Type I. Criollo, meaning "native-born", is the finest for flavor and is

classified commercially as "fine". It is cultivated in quantity in only a few countries, and Venezuela grows much of it. Nicaragua, too, is famous for it, and the Nicaraguans consider their product, cacao del pais, to be unsurpassed.

Type II. Forastero, meaning "stranger", has three subtypes. The great bulk, 80% to 85%, of the world's crop comes from this variety. It is grown in all cacao-producing regions and bears the largest fruits.

Type III. Calabacillos, meaning "little pumpkin", is the poorest quality commercially. Its pod is the shortest and its beans are flat and ferment slowly. However, it produces many pods per tree and is fairly resistant to disease. This latter characteristic is important because cacao planting is one of the most profitable of tropical agriculture, and extensive damage has been done to the Criollo and Forastero varieties by witch's broom and pod-rot disease.

Most chocolate manufactures are blends of ordinary and fine grades, according to individual trade formulas. The U. S. is the largest consumer of cacao and imports without duty over 40% of the annual world production of over 1 billion, 700 million pounds. Although the U. S. takes two-thirds of Latin-American exports, it receives over half its total supplies from Africa. Basic chocolate products manufactured in the U. S. are valued at nearly 100 million dollars a year, and in 40 years the U. S. per capita consumption has increased from one to five pounds of chocolate products annually.

Production. Though cacao is a native of tropical America, the Gold Coast of West Africa is the chief source of the bean today, accounting for 35% of the world's cacao exports. Brazil produces 17% and is increasing her quantities annually, with cocoa now ranking third in value of all Brazilian exports. Growing wild in the Upper Amazon, it was first cultivated in the State of Para in 1740. In 1836 it was introduced into the State of Baía (Bahia) which now produces 90% of the Brazilian crop, an industry that is stimulated and regulated by the Cacao Institute of Baía, founded in 1931. A warehouse with a capacity of 250,000 bags has been built at the port of Bahia. Until 1900 more than 80% of the world's cacao crop was produced in its original habitat—tropical America—but to-day the approximate percentage distribution of world production is as follows: South America's 24% together with 8% from the Caribbean area totals 32% from the Western Hemisphere; Africa supplies 66.6%, Asia 0.9% and Oceania 0.5%, totalling 68% from the Eastern Hemisphere.

In order of the volume exported, the specific geographical sources of cacao beans are the Gold Coast, 35.6%; Brazil, 17%; Nigeria, 13.1%; Ivory Coast, 7.4%; French Equatorial Africa, 4.1%; Dominican Republic, 3.1%; Trinidad and Tobago (exclusive of re-exports), 2.6%; Ecuador, 2.5%; Venezuela, 2.2%; St. Thomas and Principe, 1.7%; Costa Rica, 0.7%; and all others about 10%. The West Indies, Central America and Mexico together produce less than 10% of the world's supply, although these areas together with Ecuador, Colombia and Venezuela have long been a source of excellent quality beans. In Ecuador cacao is the chief export, and the quality of the Venezuelan crop is unsurpassed. The United Fruit Company has aided the cacao industry by planting it on disease-destroyed banana plantations in Panama and in Costa Rica. Many of the smaller producing areas have a high home consumption of the beans. For example, in Cuba 95% of the crop is used locally, and Mexico actually imports cacao, although it also exports minor quantities. The exportable surplus of the entire Caribbean area, in fact, is far below the amounts which could be produced and

sold with great advantage to the economic welfare of the region. With this fact in mind, cacao plant-breeding experiments are being conducted by the Imperial College of Agriculture in British Trinidad.

With the constantly increasing per capita consumption throughout the world, the cultivation of this economically important plant is being, and should be, extended.

Maté

General. Yerba maté or matte, sometimes called "Paraguay Tea", "St. Bartholomew's Tea", or "Jesuit's Tea", is derived from the leaves of *Ilex paraguariensis* St. Hilaire of the holly family. The stem contains only 0.73% caffeine, but the leaves possess 1.25%. It is closely related to cassine or dahoon (*I. vomitoria* Aiton) of our southeastern coastal region where the leaves of this latter species have been the source of a minor beverage known as Cassina tea or Black drink. Maté has been long known as a potential native drink, but the North American species has never gained the acceptance accorded to the South American plant, even though the U. S. government tried to popularize it in 1923 by serving Cassina tea, a carbonated soft drink, and Cassina-flavored ice-cream to 60,000 employees of the U. S. D. A. A soft drink based upon maté and natural fruit juices has just appeared as a fountain concentrate and in the bottled form on the U. S. market in 1947 under the trade name "Matey". Two companies have been organized to manufacture it. One of them, The Matey Co., Inc. of New York, is promoting its product with a $200,000 advertising campaign through the media of newspapers, point-of-sale and radio; and the other, Martay, Inc. of Kansas City, Missouri, is sponsoring its product in that area.

Ten million South Americans drink their maté daily, and quantities of it are shipped not only throughout South America but also to Europe and the United States. The plant is one of the most important botanical possessions of the temperate zone of South America. Utilized for centuries by the Guaraní Indians, it was planted first about 1600 by the Jesuit missionaries in the Guayra Province in southern Brazil, in 22 mission areas that today constitute Argentina and along the Upper Uruguay river. The beverage is prepared usually by pouring nearly boiling water over the broken leaves in a gourd and drunk when cooled sufficiently to be swallowed comfortably. It is also brewed in tea pots and served in cups in the cities of South America, and usually in this form in North America also. The gourd method is the universal one in the rural areas.

The beverage became known as "maté" or "cúya" which mean gourd, for it is from a gourd that it is drunk or sipped through a "bombilla" ("bombilha" in Brazil). The gourds are decorated, often elaborately, and the bombillas are native reeds or bulb-shaped or spoon-shaped strainers of nickel or silver.

Great quantities of cultivated maté are grown in southern Brazil, Argentina and Paraguay, while "native" or wild maté is found over a large area in the valleys of the Paraná, Paraguay and Upper Uruguay rivers. Soil composition and atmospheric conditions affect the flavor and quality of the beverage, the flavor being "strong" or "mild" also according to the region of growth. Most maté is collected from wild plants and is known commercially as "native" maté in contrast with the cultivated product, known as "plantation" maté, produced on a smaller scale in Paraguay and in Brazil, chiefly in the States of Rio Grande do Sul, Paraná and Mato Grosso. Twenty-five acres of wild maté growth yields 2 to 4½ tons (2000 to 4,500 kilograms) of crude maté.

In the cultivation of "plantation"

maté, the young trees are pruned annually up to the third or fourth year to maintain a proper form and height of 10 to 20 feet. Harvests may be made every one, two or three years. Full productivity is reached in about ten years, and the average life of a tree of good yield is about 20 years if kept well pruned and cultivated. An average yield is about 10 kilos of dried maté per tree.

In Brazil maté is grown largely in the native state in forest areas cleared of everything but pine and Yerba Maté. In Argentina it is grown in cultivated plantations; and in Paraguay it grows wild on large tracts, though some plantations have been developed. Uruguay does not produce it on a commercial scale, but it is very popular with the Uruguayans who import over 44 million pounds annually.

FIG. 24. Fruiting (left) and flowering (right) branches of yerba maté. (*Courtesy The New York Botanical Garden.*)

Preparation. Preparation of maté involves several distinct steps which are

given an ever-increasing attention to assure a better and more uniform product. The sequence of events is cutting, toasting, breaking, drying, threshing (beating), sifting, aging and manufacturing. If carefully and properly conducted, cutting is a more elaborate process than China tea picking. The maté gatherer cleans the tree of vines, then climbs the trunk or uses a ladder and cuts off the smaller branches. A number of leaves are left at the extremities of the larger branches to provide for the breathing requirements of the tree. These tufts of leaves are known as "bandoleiras." Leaves for maté are harvested only on sunshine days between 8 A.M. and 5 P.M. when no dew or rain occurs and the leaves are not damp. Primitive Indian methods combine the toasting and drying processes by placing branches with leaves in an excavation in the ground and burning bonfires around it until the leaves are sufficiently dry to be beaten off. More recent methods utilize three separate procedures. To toast (Sapeco) leaves the operator holds the branch so that the green leaves are exposed directly to the fire for a few seconds, but turns the branch continually so that the leaves are not burned. Toasting cracks the leaves open, simultaneously reducing the moisture content 25%, and coagulates or vaporizes the gums and resins so that they do not spread through the leaves and turn them black as they do in natural wilting. The total weight of the leaves is reduced one-third.

The breaking (Quebramento) process consists of removing the short leaf-bearing branches from the larger branches, so far handled, and gathering them into sheaths for drying. Drying is accomplished by the Carijo or by the Barbacua method. The carijo is a platform of poles about six feet above ground with fires one and a half to two feet apart underneath this loose platform and carefully watched to see that the leaves on the platform are not singed. Smoke can not be entirely avoided, and this affects the taste of the beverage undesirably. The process requires 12 to 24 hours. Then the leaves are broken off. A better non-smoked product is obtained if the leaves are subjected to less smoke than it is possible to prevent in the Carijo method. The improved Barbacua method in its original form involved the Tatuape of Paraguay which consists of a low, dome-shaped, loosely formed structure of bent poles, or of bricks in modern plantations, over which the broken maté is spread, completely covering it. Hot air is conducted into this dome-like structure by a tunnel from a fire some distance away, so that smoke directly on the leaves is avoided. The leaves are turned frequently, and the process requires five to 15 hours. Threshing separates the leaves from the twigs by beating with sticks on canvas or planks spread over the ground. The resulting mass of broken leaves, bark and twigs, constitutes "maté cancheado" and can be used in this form. Modern mechanical threshing is known as "trituration". It uses a crude sort of threshing mill, operated by animal, water or steam power, and breaks off and shakes the leaves through a grate. Next, the leaves are sifted (the peneiraçao process) through a coarse sieve of bamboo and then through a fine sieve.

Ageing for a few months improves the aroma and flavor. The crude product, if handled properly, is packed dry, but not air-tight, in sacks of 30 to 60 kilograms each, and sent to the factories (engenhos or usinas). In the final manufacturing of the product, the maté cancheado is refined in factories principally at Curityba, Paraná. Since maté absorbs moisture rapidly, it is re-desiccated to protect it from molding; this additional heating, furthermore, activates the chemical constituents of the maté and thus aids in developing its flavor. It is then passed through blowers and sieves to be graded

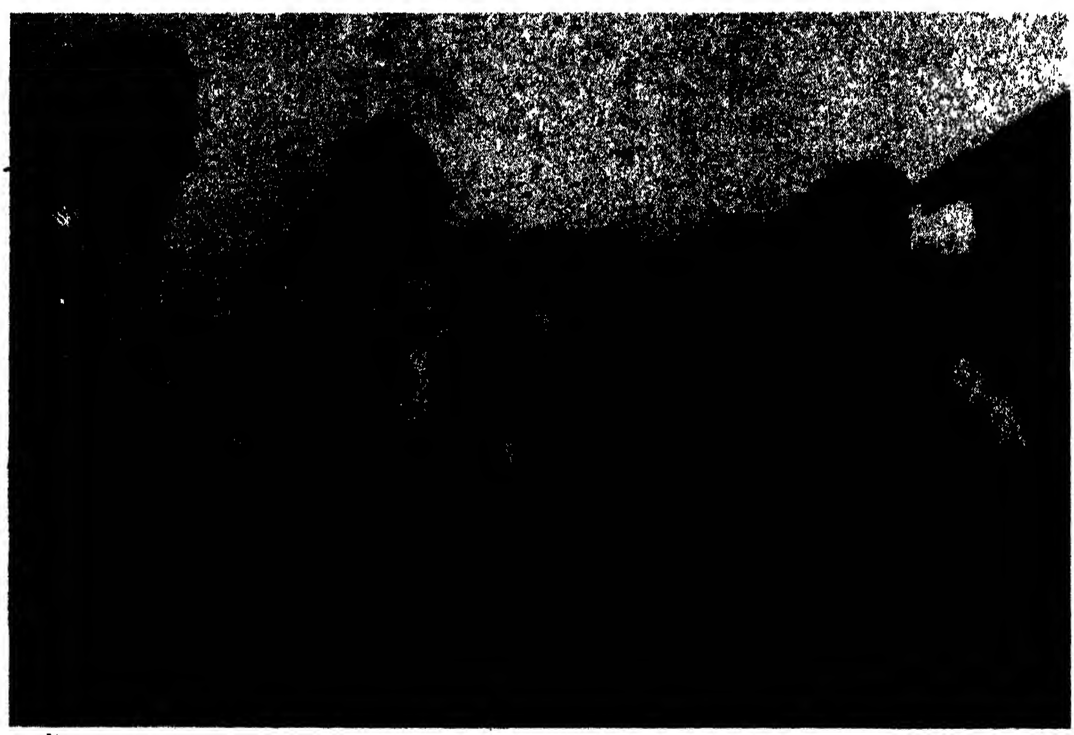


FIG. 25 (*Upper*). Gathering leaves from cultivated seven-year-old yerba maté trees in Argentina. FIG. 26 (*Lower*). Argentinian cowboys, or gauchos, enjoying their bitter maté or cimarrón. (*Photos courtesy Pan American Union.*)

as to size. Next it is blended, since the different producing areas with their various soil, climate and curing conditions impart distinctive qualities to the maté. The milled or refined manufactured product is known as "maté beneficiamento", of which there are more than 80 brands on the market. Originally transported in raw-hide bags, the product is now packed in various containers to keep out dampness by cloth cylinders, tins or water-proofed paper and cellophane sacks.

Brewing. There are several methods of preparing the infusion for beverage purposes. "Bitter maté" ("cimarrón" or, in Brazil, "chimarrão") is brewed in a gourd without sugar. If sugar is added it makes "sweet maté", "maté dulce" or, in Brazil, "maté doce". Maté tea is made like China tea, but by using a maté containing rather large leaf fragments and by employing twice the quantity per cup that would be required for ordinary tea. Maté tea is the form used in cities and in the more patrician homes, whereas cimarrón, brewed from finely ground leaves mixed with some twig fragments, is preferred by the people of the rural districts and by the cowboys (gauchos) of the Argentina rolling plains (pampas).

Brewing is a fine art in the hands of the gaucho and other rural populations. A hollow dry gourd (maté), or sometimes a coconut shell, a cow's horn or a metal cup, is half filled with the dry ground leaves. The palm of the hand is placed over the opening, the gourd is inverted and shaken gently to mix the powdered leaves uniformly. The bombilla is inserted at an angle and a few drops of cold water added. Then nearly boiling water is added until a froth appears at the opening of the gourd. This is the real maté cimarrón, and as many as ten brews can be prepared immediately from the same leaves, although the fifth and sixth fillings have the reputation of being the best.

Caffeine Content and By-products. The physiological effect of maté is similar to that of Oriental tea, but it has an advantage possibly for people who are overstimulated by the caffeine content of tea and coffee. Maté, according to the analysis of Peckott, possesses only 2.5 grams of caffeine per 1,000 grams of prepared leaves in comparison with 4.6 grams in Black tea, 4.3 grams in Green tea and 2.6 grams in ground coffee. Maté leaves also contain only 0.01 gram of essential oil per 1,000 grams of leaves, and thus do not induce the gastric disturbance which some people experience from coffee because of the oil content rather than the caffeine in the latter. Coffee contains 0.41 gram of oil, and tea from 6.0 to 7.9 grams, compared to 0.01 gram in maté per 1,000 grams of leaves.

As a by-product, considerable purified caffeine is derived from maté, and six factories in the Brazilian States of Paraná and Santa Catarina carry out the extraction process commercially. Maté leaves also have a chlorophyll content three times that of oriental tea leaves, a quality that has made them a commercial source of chlorophyll. In 1942 one United States business concern ordered 11,000,000 pounds of Argentina maté for the extraction of its caffeine, vitamin and chlorophyll content for medicinal purposes and to make the vegetable coloring matter used extensively in food, air purifying and deodorant products, and by the cosmetic industry. One hundred pounds of crude maté yields a minimum of one pound of caffeine and five pounds of chlorophyll with a total market value of $22.50.

Consumption. The popularity of the beverage geographically among the 10,000,000 South Americans who drink maté daily may be noted by the annual per capita consumption in various areas. In Chili it is 112 lbs. and in Brazil 40 lbs., but in the Brazilian State of Paraná it is 44 lbs., even though that State exports great quantities of maté and is

also near the coffee-growing center of the world. Maté is the national drink of Paraguay where consumption is 34 lbs. per capita. Uruguay does not grow any commercially but consumes 22 lbs. per capita and imported over 44 million pounds in 1945 to meet the domestic demands. Argentina uses 20 lbs. and Bolivia 4½ lbs. per capita annually.

Grades. Since leaves from different producing areas possess different qualities, producing countries import as well as export maté in order to manufacture their desired blends. According to the quality, strength and aroma, the leaves are graded on the market as Paraguay (the best quality), Mato Grosso, Misiones, Paraná, Santa Catarina and Rio Grande do Sul (the poorest quality). Commercial grades, according to the Argentine Ministry of Agriculture, are Extra (50% Paraguay, 30% Argentina, 20% Brazil), Good (50% Argentina, 20% Paraguay, 20% Paraná, 10% Rio Grande do Sul) and Ordinary (an all Brazilian blend of 80% Rio Grande do Sul and 20% Paraná). A general industrial classification of maté for all purposes is Green, Crude and Prepared (refined for beverage consumption). Argentina imports exclusively the crude maté, whereas Uruguay and Chili import the prepared maté grade for the chimarrão form of the beverage.

Production and Consumption. Although consumption is confined largely to the producing and neighboring countries, the U. S. and Europe import maté in appreciable amounts. Brazil exports it to 16 countries. Recent total consumption figures cited in Table 1 offer a summarized statement of the present magnitude of the maté industry, based on the single plant species.

TABLE 1

Consumption Area	Pounds	Year
Argentina	259,000,000	1942
Brazil	110,000,000	1941
Uruguay	49,000,000	1936–1941 average
Uruguay	44,500,000	1944
Paraguay	12,000,000	1946
Chile	17,000,000	1936–1941 average
United States	442,149	1935
United States	82,763	1940
United States	23,909	1945

The U. S. consumption has fluctuated and decreased in recent years because of high price (70¢ to $1.00 per pound) and less advertising, and due to the fact that rapid introduction of a new beverage is difficult in a country where tea and coffee have an established popularity in the habits of the average citizen.

In 1935 Argentina set up the "Comisión Reguladora de la Producción y Comercio de la Yerba Maté" to limit, control and improve the market, and in 1938 Brazil created the "Instituto Nacional do Maté" to protect and coordinate trade in maté, and to encourage consumption. Paraguay has no similar organization but does restrict exports to assure adequate stocks for domestic consumption.

The 1943 production and export figures, according to the Pan American Union statistics, appear in Table 2.

Yerba mate is the most popular beverage in the South American geo-political areas discussed here. All immigrants, Spaniards, Portuguese, Germans, Polish and other foreign constituents of the population have learned to enjoy this beverage of the original Indian tribes and of the current civilians of long standing. Theodore Roosevelt must have thought well of its taste and effect, for he recommended maté for the U. S.

TABLE 2

	Production in Pounds	Crude Exports Pounds	Milled Exports Pounds	Total Exports Pounds
Argentina	182,981,800	....	301,107	301,107
Brazil	158,731,200	60,800,676	45,105,508	105,906,185
Paraguay	36,305,352	13,977,004	230,758	14,207,784

soldiers in his book, "Through the Brazilian Wilderness". It certainly has the potentialities of pleasing flavor and of a desirable beneficial effect physiologically, all of which are necessary to promote it for a commercially successful world-wide beverage and to recommend it as possessing a healthful advantage to the consuming public.

Guaraná

Guaraná is the chief beverage of the State of Mato Grosso in Brazil, where 60% of all commercially produced guaraná is consumed and where it is in greater demand than coffee or maté as a daily beverage. Possessing a high tannin content (5%) as well as the highest caffeine content (5%) of any plant in the world, the beverage, so unusually rich in both these substances, serves the body as a stomachic and as an invigorating stimulant at the same time. Thus this beverage has the reputation in some parts of Brazil of being superior to coffee and tea as a healthful drink, and extravagant claims have been made for it. Guaraná, sometimes misleadingly called "Brazilian chocolate", has beverage qualities which might be described as slightly bitter, astringent and acid. It is enjoyed generally by people of all nations travelling in Brazil, and would become undoubtedly a welcome addition to the tremendous soft drink industry of the United States if Brazil could develop her agriculture and industrialization of guaraná so that she could supply the necessary volume of the guaraná paste, hard form or fluid-extract to meet the demand. The U. S. has long been a buyer of the meagre surplus available for export, and has used this limited supply mainly for medicinal treatment of neuralgia, certain cardiac conditions and intestinal disorders. The Amazon region of Bolivia is a relatively large purchaser of the paste and the bottled beverage.

The source plant is *Paullinia Cupana* H.B.K. of the Sapindaceae. It is a large, vigorous, creeping plant which produces bunches of nut-like fruits. Each round, brown seed is about the size of a hazelnut with a white, mealy covering. The plant blossoms in July, and the fruits are picked from October to December. Preparation of the hard guaraná bars, sticks or pan-cake forms is still very primitive. The ripe bunches of nuts are first soaked in water to open them. The seeds are then roasted, the seed coats removed and the seeds ground in a mortar to form a homogeneous plastic mass which is moulded into the stick form up to two inches thick and six to 12 inches long. Sometimes it is made in the form of bars or as flat pancakes weighing a half pound. The very dark reddish-brown or brownish-black stick form, the most common shape on the market, looks like a large petrified sausage. The roasted seeds are sometimes sold before grinding, and a powdered form is also known.

The native distribution of the species seems to be bounded by the southern border of the Amazon river and the area of the Madeira, Maués, and Ramos rivers. It also occurs in the Upper Orinoco and Negro river regions. Guaraná cultivation is chiefly in the State of Amazonas with a total planted area of less than 1,200 acres, mostly in the Maués district. Minor acreages are cultivated in the districts of Parintins, Itacoativa, Urucutituba, Barreirinho and Borba. Although the white population prepare their guaraná in a manner similar to that of the Indians, the Indian product from the Canumá and Maués-Acu river areas is considered to be of better quality. These Indians choose their seeds more carefully, and they make the beverage for themselves on the same day. Their modelled-stick form of the marketed product is sought as representing the highest quality.

Although guaraná has been consumed by the white population of Brazil for over a century, the production surplus for export to other white-populated lands has never exceeded 100,000 kilograms per year. The following tables convey the magnitude of the total production, export and destination figures of this beverage:

Guaraná Production

1938	155 metric tons	One metric ton is equivalent to 1,000 kilograms
1939	211 " "	
1940	172 " "	
1941	111 " "	
1942	95 " "	

Exportation from Manáos, Brazil

1935	52,205 kilograms	One kilogram is equivalent to 2.2 pounds
1936	53,354 "	
1937	30,034 "	
1938	36,072 "	
1939	99,676 "	
1940	3,816 "	
1941	2,733 "	

Exports reached their greatest quantity in 1939 when the distribution was as follows:

Poland	91,002 kilos
Germany	7,900 "
France	400 "
United States	228 "
Surinam	146 "

In 1942, for the first time, the quality of commercial guaraná was standardized. The fluid-extract is used in the manufacture of a refreshing beverage, in confections and as syrup, all three of which are enjoyed within the limited growing areas of the plant. Its very great possibilities as an ingredient of soft drinks and summer beverages have not been realized outside of Brazil.

Major Beverage Habits of the Geopolitical Areas of the World

General. A brief survey of the world's beverage plants and of their geographic production and consumption areas convinces one of the popularity of tea throughout Asia, the U. S. S. R., the United Kingdom, Canada, Australia, the Union of South Africa and other lands populated primarily by the English. The Western Hemisphere, with the exceptions of Canada (tea) and the yerba matte-drinking areas of southern Brazil, Argentina, Paraguay, Uruguay and Chile, possesses primarily a coffee-loving population with tea occupying a secondary but important place. This fact is also true of continental Europe, the Near East and most of Africa.

A glimpse at the beverage habits of various geographic regions of the world reveals also that local botanic sources are available everywhere, ranging from a few to a multitude of species and that dependence upon beverage plants ranges from the use of practically no native species, where dependence is entirely upon imported products, to areas which find satisfaction largely from native species and import very little.

Australia. In Australia, where neither tea nor coffee is grown on any substantial scale and no significant native beverage plants exist, except fruit, tea from Ceylon is the chief beverage, and the comparatively little coffee drunk is obtained from Java. The annual average for the five year period of 1935–1936—1940–1941 for tea consumption was 48,050,000 pounds and for coffee during the same period only 5,533,000 pounds. Fruit juices are consumed in great quantities and over one million gallons a year (1,044,202 gallons in 1944–1945) are exported, derived from tropical fruits grown chiefly in Queensland and New South Wales. Other fruits from these same areas and from Victoria, South Australia, Western Australia and Tasmania contribute to the total volume.

South Africa. In the Union of South Africa coffee is not produced successfully, and the amount of China tea (*Thea sinensis*) grown supplies only about 1/20 of the demand by the English-speaking population. The native

population consumes the "bush teas" derived from a half dozen wild species of the region, especially the leaves of *Athriscia phylicoides* D. C.

Canada. Canada, like the United States, has a native flora of many species which have been used for beverage purposes, but their utilization is largely historical. Canada depends greatly upon importation of tea and coffee for her non-alcoholic beverages, but fruit juices, cola and other soft drinks are common, and a small grape juice industry exists there. Apple juice and cider, too, are abundant in season, and during the summer of 1944 Nova Scotia shipped 200,000 barrels of apple juice fortified with vitamin C to Canadian and other soldiers overseas.

Iceland. In Iceland many native plants are the source of Icelandic tea, esteemed by some of the population for both flavor and vitamin content. This fact recalls the general use of rose-hip tea for its vitamin content in England during World War II because of the absence of citrus fruit juices as a major source of vitamin C in the diet. In 1945 Iceland imported 866,782 kg. of coffee, 12,557 kg. of tea, 176,627 kg. of chocolate, 23,018 kg. of cocomalt, 900 kg. of lemonade and 150,127 kg. of fruit juices, in addition to alcoholic beverages, for a population in December, 1945, of only 130,356.

Continental Europe. Denmark depends upon imports for her coffee and tea but produces much of her own alcoholic beverages, such as beer from barley and "snaps" from potatoes and corn grown primarily in Jutland.

Switzerland, in addition to an extensive viticulture for both red and white wines, devotes a considerable percentage of the apple and pear crop to the production of sweet cider and fermented cider which is consumed locally and on the rest of the Continent. Apple cider

FIG. 27. A Swiss crop of apples destined for cider manufacture. (*Courtesy Consulate General of Switzerland, New York.*)

is popular in numerous countries, and in 1945 the U. S. imported 477,007 gallons valued at $864,395, chiefly from Canada with smaller amounts from Spain and Argentina. Switzerland and Czechoslovakia have a minor commerce also in native herb teas but are entirely dependent upon imports for their China tea and coffee. Czechoslovakian vineyards are in the sheltered regions of Bohemia, Moravia and southern Slovakia. Likewise, Estonia produces fruit juices locally and imports tea, coffee and chocolate. In Russia, tea is the common beverage, and coffee is both secondary and poor in cup quality. The opposite is true in Germany where coffee leads in consumption and tea is decidedly secondary, with beer consumption high. Similarly in Italy coffee is common but in the form of a very strong brew and is drunk with milk. Tea finds only a minor usage there and wine is the major alcoholic beverage.

Turkey prepares a number of beverages from local flowers, leaves, roots and seeds, some of which are most unusual, such as the radish juice used only in southeastern regions of the country. Turkey's annual consumption of China tea is approximately 20 tons, and of coffee, 600 tons. Greece also uses a large quantity of native teas known as Greek Mountain Tea, made particularly from linden tree flowers (*Tilia vulgaris, T. alba* and *T. argentea*) and the leaves of six species of *Sideritis*. These plants, however, do not create an extensive item of commerce, since each family picks its own supply in the wild state. Coffee is consumed throughout Greece, but China tea is seen chiefly in the cities, and cocoa is rarely served outside of metropolitan areas.

In France, wine is the beverage of greatest consumption, as the average Frenchman does not usually drink water with his meals. Viticulture is a major industry, and France is the largest producer of wine in the world. Ninety-five percent of French grapes are transformed into wine or derived distilled products with an annual output of over one billion gallons. Dry wines are made from grapes of high acid and moderate sugar content; sweet wines of grapes with high sugar content and moderately low acidity. Apple and pear cider rank second in consumption, followed in descending order by beer, coffee, tea, fruit juices, soft drinks and hard liquors. Cider is produced in the northeastern area where apples thrive and pears to a lesser extent. Most of the annual cider production of 20 million hectoliters is consumed locally, but small amounts are exported in some years. All parts of France, except the North, Northwest and mountainous areas, produce wine, with the bulk of ordinary wines coming from the South of France near the Mediterranean. High quality wines come from Champagne, Bourgogue, Alsace, Bordelais and Anjou. Coffee imports average (1930–1940) approximately 480,000 metric tons and tea only 1,800 tons. The effect of World War II caused such drastic rationing that the "Ersatz" coffee in France became 90% roasted barley, acorns, soybeans and date stones. In Holland coffee became completely a black market item, and the Dutch roasted and ground their tulip bulbs as a coffee substitute. The war with its coffee rationing and unavailability of distilled alcoholic drinks resulted in a tremendous increase in the production of fruit juices in France from 15,000 hectoliters in 1935 to 300,000 hectoliters in 1943.

In contrast with France, Belgium is not a very large consumer of wine, only five liters per capita, but beer consumption there is among the highest in the world at 170 liters per year. Tea has only one ounce per capita per year, which is very low. Chocolate is also not very common in Belgium, but coffee

or coffee chicory is utilized widely. Imports of coffee in 1938 amounted to 49,000 tons, indicating an average per capita use of almost 13 pounds. Coffee chicory averages 25,000 metric tons annually or about 6½ pounds per capita. About 90% of the Belgian production of coffee chicory root is in the Province of Western Flanders. Exports of coffee chicory average 20,000 to 30,000 tons per year.

Portugal's citrus fruit juices and wines, especially port wine, are produced at home, and coffee in her colonies, but she imports all her tea and coffee for home consumption. Spain, like France, has extensive vineyards over the greater part of the country, and the per capita annual consumption of wine is 56 liters. Barley is likewise cultivated all over Spain, but beer consumption is only 2.8 liters per capita. Barley water is drunk widely and is made by maceration of toasted barley, sweetened to taste and cooled. Apple cider has a per capita use of two liters, almost as much as beer. Cider is produced mainly in the provinces of Guipúzcoa, Asturias, Navarra and Vizcaya y Alava. Fruit juices are popular and are derived from citrus fruits, grapes, red currants, raspberries and pomegranates. Among the soft drinks, sarsaparilla is common. Two unusual beverages from botanic sources are "orgeat of chufas" (Horchata de chufas), prepared from the tubers of chufa (*Cyperus esculentus*), and soybean milk (Leche de Soja) which is produced mainly in the province of Valencia. Use of the latter is beginning to spread, and the world's greatest producer and consumer of this botanical milk is Manchuria in Asia. Spain imports all her tea, chocolate and coffee.

Latin America. Nearly all the 21 countries represented in the Pan American Union produce and consume coffee, many deal in cacao, a few in yerba maté and very few in Oriental tea. There are also a number of interesting beverages derived from native plants. Some of them are to be recommended highly for much more widespread utilization. Haiti produces coffee in the mountainous regions and exports nearly 30 million bags annually. As a beverage, Haitians prefer black demi-tasse coffee or café au lait, the Haitian coffee with milk. Nearly 1⅓ million kilograms of cacao beans are exported annually which are grown in the valleys at the base of the mountains. Milk is nearly always added to the beverage form. Fruit juices are numerous in Haiti, which, in addition to those of citrus varieties, include the juices of the sour-sop (*Anona muricata*), the melon (*Citrullus vulgaris*), the granadilla (*Passiflora quadrangularis*) and pineapple (*Ananus sativus*), as well as coconut milk (*Cocos nucifera*); there is also a beverage prepared from the bark of mabi (*Colubrina reclinata*) as well as a considerable list of herb teas and alcoholic beverages used by the Haitian population.

Cuba, a producer of excellent coffee, also enjoys an appreciable number of fruit juices and beverages from native-grown plants. Mexico and Guatemala are producers of coffee and cacao, and their people, like all other Central Americans, are heavy coffee consumers. Guatemala is also a producer of China tea. Other drinks used in Guatemala are atole (corn flour gruel type) and aqua masa (fine corn dissolved in water with sugar added), and the natives of sugar cane regions consume a variety of intoxicating beverages derived from the cane and known as "Boj" and "Guarapo". Many other juices, fermented and unfermented, are also employed, such as those of tamarind, pineapple, custard apple and orgeat.

Bolivia, Peru and Chile all consume coffee, but a very common beverage in Bolivia and Peru is "chica". Chili also uses appreciable quantities of Yerba

Matte. Bolivia annually consumes one billion liters of chica prepared from corn and a half million liters of "pisco" from grapes. Chica has been common since the days of the Incas who consummated their feasts with chica quaffed from golden goblets. El Salvador is primarily a coffee-producing and consuming country. Colombia is credited with growing on the highlands the bulk of the finest mild coffee. Venezuela, in addition to its coffee grown largely in the States of Táchira, Trujillo, Lara and Mérida, also produces cacao, especially in the States of Miranda and Sucre. Tea is not produced and its import and consumption volume are not significant. Chocolate consumption is only one gram per capita per year. Everybody drinks coffee. The chief imported caffeine-containing beverages are Coca-Cola and Pepsi-Cola. Great quantities of drinks made with soda water and originating from natural gaseous water are consumed under the name of "Sodas" and "Granadinas".

The most common native beverage in Ecuador is "naranjilla". It has been selected in its fresh state by the Ecuadoreans from among all beverages as excelling for its delicate flavor and exquisite taste. The principal reason for its popularity being limited to Ecuador is the fact that pasteurization or other preservative processes tend to destroy its fragrance and color. In 1939, however, one Ecuadorean firm succeeded in sending 1,500 gallons of naranjilla juice to

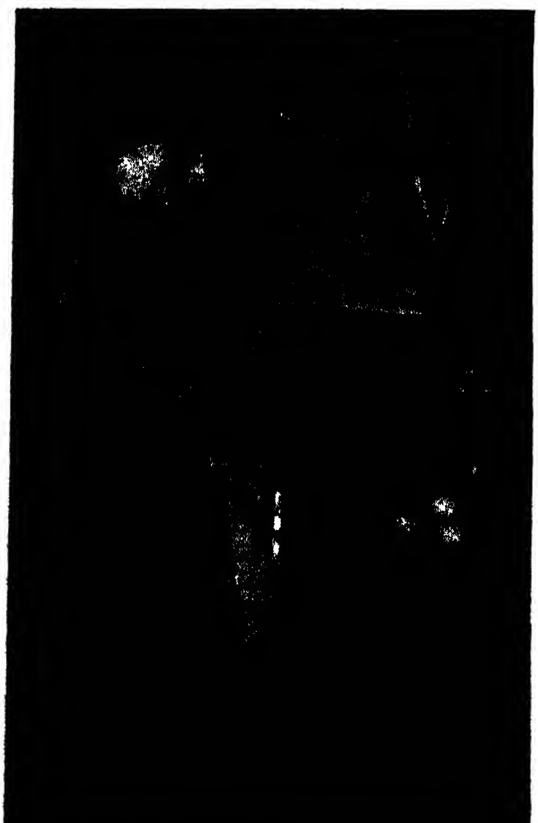


FIG. 28 (*Left*). Harvesting naranjilla fruit, *Solanum quitoense*, the basis of a popular beverage in Ecuador. FIG. 29 (*Right*). Mature naranjilla fruits with their soft white hairs. (*Photos courtesy U. S. Dept. Agr., Bur. For. Agr. Rel.*)

the World's Fair in New York, and at that time a few of us Americans had the privilege of enjoying its delicious flavor and refreshment. It was accepted enthusiastically, and with the conquering of the transportation problem it will undoubtedly become a very popular fruit juice. Botanically, naranjilla is derived from *Solanum quitoense* Lam. of the family which has given the world the tomato, potato, tobacco and the eggplant. The native name "naranjilla" means

FIG. 30. Bags of naranjilla fruit ready for market. (*Courtesy U. S. Dept. Agr., Bur. For. Agr. Rel.*)

"little orange", but it would have been more appropriately called "tomatilla" because it resembles the tomato more than the orange, except for its golden color. The plant is a bush, six or eight feet tall, with large leaves sometimes 16 to 18 inches long with dark green upper surfaces and light green lower surfaces with scattered violet spots. The small white flowers in corymbs develop into round, bright orange fruits, about two inches in diameter. Fruits, leaves and branches are covered with a soft white fuzz that is lost during harvesting and handling. The natives on sloping hillsides of the middle altitude valleys of the rain forests harvest the naranjilla weekly the year round. The plant bears continuously with no special care other than one weeding operation each year during its three-year crop life. It bears fruit 14 months after the seedling is transplanted and continues for two years. Each acre bears 730 plants and yields from 180 to 360 bags of fruit weighing 125 lbs. each. Naranjillas tend to exhaust the soil, so that after a fruiting period on newly cleared land, the area is not good for subsequent crops, other than bananas or sugar cane, unless especially treated with fertilizer. Naranjillas are very sensitive to ecological conditions and develop best on well drained slopes at 4,000 to 7,000 feet elevation between latitudes 2° N and 5° S. This includes practically all of the Ecuadorean Andes. Ecuadoreans produce 2,000 tons of the fruit annually, two-thirds of which are grown in the Bãnos region of southern Ecuador. Guayaquil is the largest consumer and is the region where most of the crop is sold.

Naranjillas are consumed principally as a drink, although naranjilla marmalade is packed commercially in Quito and naranjilla pie is a choice treat among Ecuadorean hostesses. The juice is most healthful because of its content of pepsin and 1.5% proteins (albumen), with lime, phosphate and magnesium ranging from 0.98% to 1.6% of the total juice. When sugared and stirred, it makes a delicious foamy drink. It is sweet yet possesses a tartness suggestive of a combination of orange, pineapple and tomato, and has a distinctively refreshing fragrance. May Ecuadoreans find a way to successfully ship their choice beverage throughout the world.

Conclusion

Juices from home-grown fruits and soft drink consumption increased enormously in all countries, due to war re-

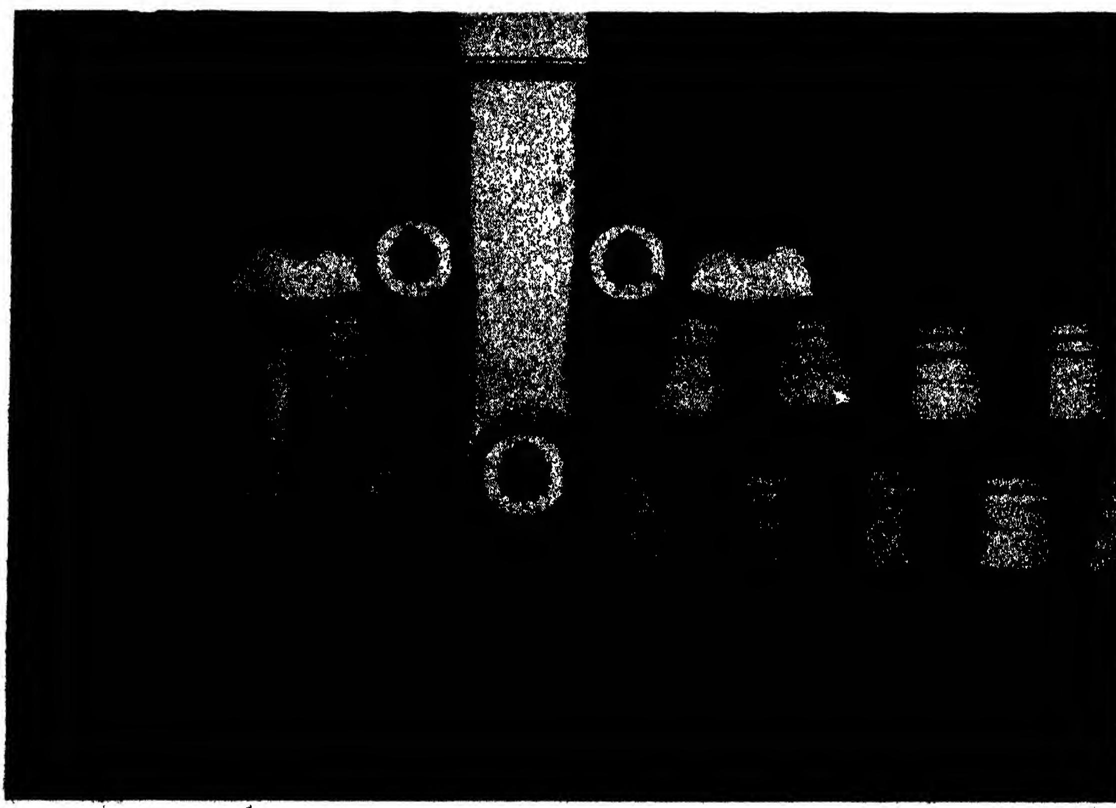


FIG. 31 (*Upper*). Naranjilla plant in flower, Province of Tunguzahua, Ecuador. FIG. 32 (*Lower*). Naranjilla juice in 13-gallon barrels for shipment to the New York World's Fair, 1939. (*Courtesy M. Chalons, Asesor Comercial y Agricola, Quito, Ecuador, and B. Oquendo, Vice-consul, Consulado General del Ecuador, New York.*)

strictions by law or by interference with importation. Because of the mineral and vitamin content and general healthful nature of such drinks, it is hoped that the consumption of these refreshing contributions from plant life will remain high on a per capita basis. The United States with her international population shows the greatest interest in the variety of fruit juices and combinations of them; also in carbonated soft drinks; but we, like all global and national areas, would do well to learn from our neighbors. We could advantageously adopt still more of the available array of beverages which would be refreshing, stimulating and healthful additions to our daily diet. This would create by their exchange, a greater utilization of native plants and an increase in employment, and thereby improve international commerce and good will between various geo-political regions. The soft drink and fruit juice industry is the beverage category in which the largest number of introductions throughout the world can be made by a global use of cola drinks, the successful shipping of naranjilla from Ecuador and a wider familiarity with yerba maté from Brazil, Argentina and Paraguay. An extension of the beverage form of the North American cranberry would also be desirable. It is a crop of 50 million pounds annually which possesses a natural tang and needs little or no fortifying. It is acidulous, pleasant and refreshing, and mixes to advantage with pineapple and orange. Its ten minerals and five vitamines make it healthful. The South American melon tree, papaya (*Carica papaya*), with its mild and satisfying flavor is finding popularity in the United States. The passion fruit which is related to our southern Maypops, has an attractive cranberry-like flavor. It was imported from Australia until the war and has been cultivated on a small scale in California. The whole fascinating question of carbonated teas, too, lies dormant on the doorstep of the beverage industry. May the re-establishment of world peace and more stabilized conditions of international commerce bring more time for the science and art of providing global enjoyment of all the best beverages. They are healthful items of the daily diet, and pleasing the sense of taste is an essential factor in good digestion and better living for everyone.

Utilization Abstracts

Soybeans. Foam fire-fighting apparatus for oil tanks, *etc.*, involves not only the reaction of carbon dioxide-producing chemicals but also an ingredient known as a "stabilizer" which prevents too rapid dissipation of the carbon dioxide through the foam. This ingredient is usually a product that possesses colloidal properties and that is derived from plant materials, the most prominent of which have been aqueous extracts of soap bark [inner bark of *Quillaja saponaria*, a tree of the Peruvian and Chilian Andes] and of licorice root [*Glycyrrhiza glabra*, an herb of Mediterranean countries]. During the exigencies of the recent war, however, particularly on ships, soybean protein [*Glycine soja*] was found to surpass soap bark and licorice for this purpose. During the war years over five million gallons of foam liquid were produced from soybeans, and in 1944 alone 900,000 bushels of the beans were thus used. This use took about 40% of the total industrial consumption of soybeans that year, and added one more to the already known more-than-one-hundred primary uses of the beans. (*J. M. Perri, Chemurgic Digest 5(12): 209. 1946*).

Taro—*With Special Reference to Its Culture and Uses in Hawaii*

A staple food since ancient times for countless Pacific island natives, taro may today be entering a new era of utilization by way of the baker's flour manufactured from it and other comestibles such as poi and paiai derived from its corm.

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Description

TARO (*Colocasia esculenta* (L.) Schott) has been an important root crop for millions of people for well over 2,000 years. Probably originating somewhere in southern Asia, it has spread with migrating peoples to all corners of the tropical and subtropical countries of the world. It is a stemless, rank-growing aroid, conspicuous for its 18-inch to seven-foot tall tuft of petioles and pendant heart-shaped leaves which make it look like an overgrown version of its close relative, the caladium. Beneath the ground are a large fecular corm and its surrounding dormant or sprouting tubers; or, as in some varieties, an abundance of lash-like stolons devoid of tubers. The inflorescence is yellow and similar in shape to that of the skunk cabbage.

Because of their antiquity and vegetative reproduction both the genus and species are confused and extremely variable in size, shape of the corms and leaves, coloration of the leafy parts and rarity of flowers. By study of the chromosome structure this confusion will no doubt be clarified. Today there are probably about 1,000 horticultural varieties grown, each differing in some respect from the others.

Calcium Oxalate Content

Anyone who has tasted any part of an aroid is well acquainted with the prickly feeling throughout the mouth and throat a few seconds later, due to calcium oxalate crystals in the juice. Taros, as a rule, although containing a generous supply of this substance, are variable, some varieties being more acrid than others. The exact cause of this unpleasant sensation was discovered in 1836 by Turpin who saw microscopically small cigar-shaped capsules of a gelatin-like nature, open at one end, that when wetted eject crystalline spears, or raphids, into the surrounding tissues. Further study by later investigators has shown that it is this mechanical phenomenon, not the chemical action on the skin, which is irritating. They found that the surest method of eliminating this "itch" is thorough cooking, although drying lessens it considerably. Cooking breaks down the capsule, releasing the raphids, which remain unchanged, but harmless, throughout the tissues.

Old World History

Although well established as a food plant in India and Malaysia, the first known written records of taro come from China where references are found in a dictionary and a materia medica which considered the leaves, and particularly the seeds, of value for indigestion and flatulence, and for parturient women. The plant must have arrived in Japan at an early date from either China or the

Asian mainland, as there are many varieties there very similar to the Chinese. In Japan the plant is called "imo", whereas in China it is known as "wu". Taro has always been a common staple in Japan, but is considered a delicacy in China. The first taro introduced to Sweden was brought from China in 1754 by Magnus von Lagerstroem as a hothouse curiosity and called *Arum Chinense*.

The first western records of taro are from Pliny (23–79 A.D.) who saw it growing in Egypt where it was often eaten and exported to Rome. It arrived there through Arabia where it is still called "culcas", a name that was slightly varied upon its Egyptian arrival to "qolqas". Its generic name is derived from the Greek word for the lotus with which the taro was often confused. We can be quite certain that taro was not in Egypt in ancient times, for there are not any hieroglyphics of it, as would be most likely had it been there. From Egypt, we can presume, the plant went farther west and north at later dates to Portugal and to the many Mediterranean islands where it can be found today naturalized along streams and wet places.

New World History

Taro was the important food of French Tropical Africa when slave traders were there collecting their human merchandise for the new American colonies. These men found it cheaper and easier to let the slaves subsist on their native food; hence taro, or "eddo" as the Negroes called it, found its way to the New World. It is still called "eddo" in Barbados, and to add to the confusion there is a closely related American plant, yautia (*Xanthosoma* sp.), which, along with taro, is known also as "tanya", "coco", "malanga", "oto" and by many other names, depending on the island where the plants are found. About 200 years ago another taro was introduced from China which was called "eddo de la Chine", finally contracted to "dasheen", the plant with which Americans are somewhat familiar.

It is this taro, known to commerce as the Trinidad dasheen, which was introduced by the Department of Agriculture in 1910 into the southern States as a year round crop in an attempt to find a substitute for white potatoes, that could be grown in soils too moist for the latter. The African taro and yautia had earlier found their way to these States as slave food, but, because of their coarseness, never amounted to much. The dasheen, on the other hand, has a very delicate nutty flavor, is much less fibrous and can be prepared in any way that potatoes can. However, after 36 years of attempts to encourage farmers to grow this crop, only a few do so today, as labor expenses and early frosts provide obstacles. The major problem to be faced by farmers who grow dasheens on a large scale for out-of-state markets is foreign competition. Approximately 800,000 pounds yearly are imported into the United States from the Dominican Republic, Cuba, the Azores, China and Mexico, the magnitude of exports from these countries being in the same sequence as the sources are here listed. These countries are able to grow the plant more easily and cheaply than is the United States and in spite of duties still to undersell the American market. Notwithstanding these odds, Mr. Robert A. Young of the Department of Agriculture, one of the dasheen pioneers, still hopes that the American people will at least grow the plant in home vegetable gardens, or that farmers will continue to grow it for a limited market, since the tubers are excellent for human food and the corms make good animal fodder. Blanched shoots are forced for a winter vegetable. The elephant ear, an all green plant, regarded by some authorities as identical with taro and by others as a different species (*C. antiquorum*), is sold

by some plant growers as a summer ornamental for gardens as far north as New Jersey.

Pacific History

Taro history eastward is probably more ancient and better understood than its westward spread, but the story is still far from complete. According to anthropological theories, the Polynesian people moved down the Malay Peninsula, taking with them plants which supplied food and clothing, as well as retaining methods of planting them. They traveled along the Sunda Islands to New Guinea. From Java originates the Polynesian name for the plant which we have adopted in its Tahitian form—"tales" in Java and "taro" in Tahite, "ndalo" in Fiji, "talo" in Samoa, "ta'o" in the Marquesas and "kalo" in Hawaii. According to Dr. Peter Buck, in order that the Polynesians might keep their Asiatic economic plants alive on the long journey to the central Pacific, they had to travel northwards *via* the volcanic Caroline Islands into the Gilberts, as the shorter atoll route through Melanesia was inhospitable to these plants. This theory is well illustrated by taro culture on these low islands. Holes must be dug deep down to brackish water and filled with decayed vegetable matter before a very coarse variety of taro can be grown in them.

FIG. 1. A field of dryland taro in Hawaii, in which the crowns have been set three feet apart to facilitate irrigating and weeding. When the plants are well established they are mulched and no longer weeded. (*Courtesy Hawaii Agr. Exp. Sta.*)

The first Polynesian islands to be settled were the Samoan Group, probably 2,000 years ago. From there more adventurous or harried people pushed on to the Society Islands, a fertile volcanic land, which became the base from which expeditions set out to populate the many islands to the south, east and north.

The two places which grew taro the best and where it became the staple food were Rapa, lying to the south-west of Tahite, and Hawaii, to the far north. In these relatively cooler islands many more varieties were developed, and a fermented paste was made from the steamed corms. This paste, known as "poi", is native to only these two localities.

In Rapa poi is made in a rather haphazard manner by women, as it is considered menial work for men. They bring steamed corms to large flat stones along the edge of streams and crush the taro with any handy rock. When the mass is smooth, they add a little water and knead it as we do bread dough, incorporating as much air as possible. Then the substance is allowed to ferment aerobically for a few days, thus becoming poi. It is eaten rolled into small balls on the palm of the hand, dipped into water or lemon juice and popped into the mouth.

In Hawaii taro was of such great importance to the natives that it indirectly became the basis of their civilization and social customs. The first taro to arrive in these fertile volcanic islands may have arrived with the traditional discoverer, Hawaiiloa, who landed there in 450 A.D. It was an acrid, rather coarse plant which was held in low esteem when the Hawaiians, as we know them, arrived from Tahiti around 1100 A.D. with choicer plants. Anthropologists believe that the first waves of newcomers were of the chieftain class and naturally would have brought with them the most succulent pink-cormed varieties. In time the commoners came with their supply. As Polynesian taro corms do not keep long, "huli", which consists of a quarter inch of the top corm plus about five inches of the petioles, were used for propagating because they keep for several weeks and even months if kept moist. There are theories that seeds were used in these travels, but taro seeds are rather rare and plants from them are weak.

Most of the taro was grown in water either on valley floors or on terraces built ingeniously on steep cliffs where springs were abundant. Taro was the most important food because in many sections of the Hawaiian Islands the climate is either too damp or too dry for breadfruit, coconuts and sweet potatoes to grow in profusion. Because water is of prime importance to taro culture, it had to be portioned out, and the supreme laws of the land revolved about water distribution. So that all could benefit, a great system of canals and locks was devised for all large streams which flowed into cultivated areas. Remarkable engineering feats were accomplished. Ditches were hewn in the sides of stone cliffs. Underground waterways and great stone channels were built. These, remains of which can be seen today, belie the accepted presumption that the Hawaiians were completely primitive.

Lo'i Culture. In building their wet taro patches, or "lo'i", the men of Hawaii alone did the tedious work of measuring off areas of land 10 to 60 feet square, digging down to hard soil or rock and building reinforced walls around these pits. When this was done water was let in and a day of festivity was proclaimed. Every person of rank and of all ages joined in to wade barefoot in the pond to trample the floor. Garland-bedecked, these people frolicked in the mud, and at the end of the day were feasted by the owner of the lo'i. The next day, when the mire had settled and the water was let out, the men planted the huli. Water was let in when the first leaves had expanded and was allowed to circulate constantly about the plants. The walls between the lo'i served as narrow pathways and as garden plots on which to plant sugar cane, sweet potatoes, arrowroot and other crops. When the crop was ripe, nine to 18

FIGS. 2 & 4 (*Upper and lower right*). Corms of Japanese taro, or dasheens. The abundant dormant tubers can be stored for three or four months after harvesting, and they comprise an important article of commerce in the Caribbean area. (*Courtesy of The New York Botanical Garden and of the Hawaii Agr. Exp. Sta., resp.*). FIG. 3 (*Lower left*). Corm of a Hawaiian variety, "Mana Ulaula", with its sprouting tubers. The Mana taros are peculiar for their branched corms and are held in high esteem for taro-coconut pudding. Hawaiian tubers must be eaten immediately after harvesting. (*Courtesy Hawaii Agr. Exp. Sta.*)

months later, depending on the variety, men harvested as much as was needed from time to time to make poi. The remaining was allowed to grow until needed, and the bare places replanted with huli from the harvested crop. The tops and leaves were thrown back into the lo'i as fertilizer. Often to supplement these crops fish were raised in these plats.

Dry Culture. Where running water was scarce dry land taro in Hawaii was grown either around dwellings or on upland plantations along forest borders where the soil was rich and rains frequent. Two or three huli would be placed in a hole three feet in diameter, about nine inches deep, fertilized with weeds, fern and rotted logs of kukui (*Aleurites moluccana*). From these semi-wild gardens came taro corms which weighed up to 25 pounds with no care except occasional weeding and mulching to retain moisture. The forest land was used also to plant emergency crops for times of drought or famine. Wild taros of various varieties can be seen today growing along streams or hidden away in tangled jungles.

Poi. About 150 varieties of taro were developed in Hawaii. Most of these varieties could be roasted, steamed in underground ovens, or made into poi. However, as a general rule, certain varieties were delegated to specific uses. Taro grown in dry cultivation was considered better for general eating, and taro grown in lo'i was preferred for poi, although connoisseurs considered poi from wet culture to lack richness in flavor, even to taste of stagnant water. Chiefs ate only the pink-cormed varieties which now comprise the commercial taros. Most of the other varieties make grey pois, some darker than others. One variety makes a yellowish poi. All poi types are a matter of taste; therefore as the eater made the product he would select his favorite varieties, combining several of the same corm consistency, or one particular taro.

Men did all labor connected with taro, since it was considered too important for women to handle. After peeling the cooled corms, a man would sit at a long, shallowly-hollowed board or stone, and coarsely crush the taro with a heavy stone pestle. As the work progressed he used a lighter pestle, adding water to the poi until it was of the right consistency. Then he would place it in a gourd calabash and set it in a sunny place to ferment anaerobically. The amount of fermentation, too, was a matter of taste; if he wanted sour poi, three days of fermentation gave perfection. The poi was then put into smaller calabashes and mixed with water to the desired consistency, and eaten, usually with the first two fingers, although if it was thick the index finger would suffice. Some of the smaller bowls were carved with a flange on which to fastidiously wipe off the sticky paste before eating other foods. Today one hears the phrases "one-finger", "two-finger" or "three-finger" poi to describe various poi consistencies, but these terms are modernisms. "Three-finger" poi in ancient Hawaii was abhorred by everyone except gluttons who could get more poi with less effort by employing that many digits. An adult doing normal work ate ten to 20 pounds of poi per day, and, needless to say, excessive avoirdupois was the height of beauty.

Other Uses in Hawaii. Steamed pudding was made from grated taro and coconut as a sweetmeat. Petioles and leaves formed an important adjunct to meats, usually combined with coconut water. The Hawaiian feast, "luau", has taken its name from the leaves. As a delicacy the spadices were baked with fish or pork. Today all these dishes are highly esteemed by all races in Hawaii, who celebrate birthdays and weddings with luaus prepared in traditional style.

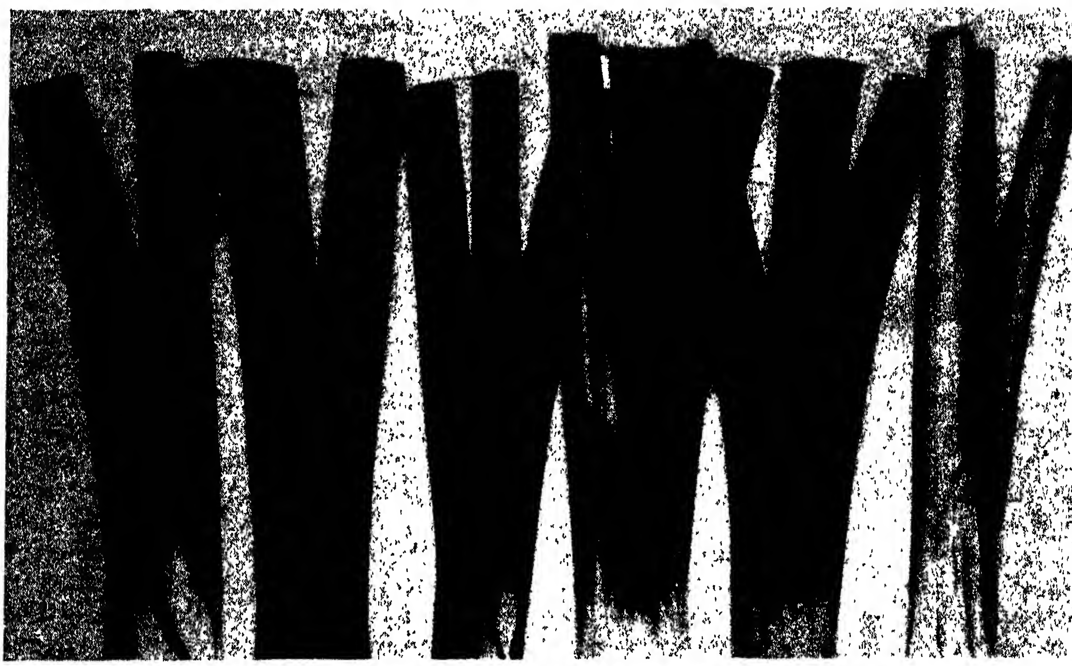

FIG. 5 (*Upper*). A nearly mature field of wetland taro. When a crop is about seven months old, just before the corms begin to mature, the water is turned off and the field fertilized; a week or two later water is allowed to enter again and to remain until the crop has matured. FIG. 6 (*Center*). Petioles of various Polynesian varieties of taro, displaying a wide range of color and much variation. There are many striped varieties in Samoa and the Dutch East Indies, as well as in Hawaii, and they offer material for very effective planting in tropical or aquatic gardens. FIG. 7 (*Lower*). Lo 'i, or wet plat, prior to planting, in which huli, or crowns, are kept fresh before

Bunches of leaves and petioles are to be found at markets.

Besides being an important item of food to the natives, many taros had medical or religious significance. To understand the reasons why a particular variety had a specific use is to understand the Hawaiian system of nomenclature. Each plant has certain differences, mainly in petiole coloring, which the observant Hawaiians carefully noted. Some were speckled like a certain bird, or striped like a particular fish; others were all bright red, or purple-black; while still others were named for the fire goddess because of their smoky coloring. One taro in particular is a brilliant red petioled variety which was named for a fish of that color. This fish was frequently used for offerings; however, if the fish were unavailable the taro of the same name could be substituted.

The juice from petioles or whole leaves was used for styptics and poultices. Raw corms of mildly "itchy" varieties were grated raw and mixed with sugar cane juice for pulmonary congestion. Very thin poi was fed to infants and invalids as an easily eaten and digested food. O. W. Barret states that there is no word for indigestion in the kanaka language. This is untrue as the Hawaiians had innumerable words describing the symptoms.[7] Poi was prescribed as a cure because the extremely small starch grain of taro and the fermented poi causes only slight irritation, if any, to sensitive alimentary tracts. Another variety was known as "ohe" or "bamboo" and was used medicinally for clysters. This taro had an extremely hard corm and was acrid, which made it unsuitable for eating, but it was often grown for the sole purpose of supplying suppositories, for which its properties were well suited. Debilitated persons were bathed in thin poi which was allowed to dry on the body, as it was supposed to improve muscle tone. Thrush was evidently a very common disease among Hawaiian children and consequently many remedies are extant. One of these is a mixture of a mild taro, raw and grated, and burnt coconut meat.

Nutritional Experiments. Today these ancient medical and religious uses for taro in Hawaii are all but forgotten except in isolated, rural communities. However, not forgotten is the fact that the old Hawaiians had extraordinarily good teeth and physiques which were built primarily by taro, eaten in conjunction with fish and seaweed. Following this presumption, Dr. Nils P. Larsen of Honolulu persuaded the Hawaiian Sugar Planters' Association to let him try a nutrition experiment with the people on one of the sugar plantations. These people were for the most part Orientals whose chief food, primarily because of racial tastes and for economy, was polished rice. Their teeth and bones were extremely poor, general health far below par, and infant mortality high, due to inferior nutrition and physical hygiene. Substituting taro for rice in the diet, Dr. Larsen proved that taro was the factor in the fine physiques of the old Hawaiians by showing the vast improvement in health of the plantation population. In 1935, as a result of Dr. Larsen's investigations, the Honolulu Sugar Planters' Association received a large grant of money from the Federal Government with which to carry out certain experiments. $50,000 of this was set aside for investigations into nutritional uses, agricultural methods and diseases of the taro plant.

Tests showed that the corm, when steamed, was a high energy food containing about 30% starch and 3% sugar. Moisture was 61%, protein a little over 1%, with a trace of fat and crude fibre. The ash produced is alkaline. When eaten in quantity, as it usually is, taro is a good source of highly assimilatable calcium and phosphorus. Other minerals

are present, but in smaller quantities. The vitamin content is similar to that in white potatoes, except for thiamin, of which taro is a greater source. The leaves and petioles when cooked are excellent sources of vitamin A and a good source of vitamin C.

The greater part of the investigation was to find out what use could be made of the corm commercially. In the past, various trials had been made to make flour. The first attempts were made in 1823 by the American missionaries who

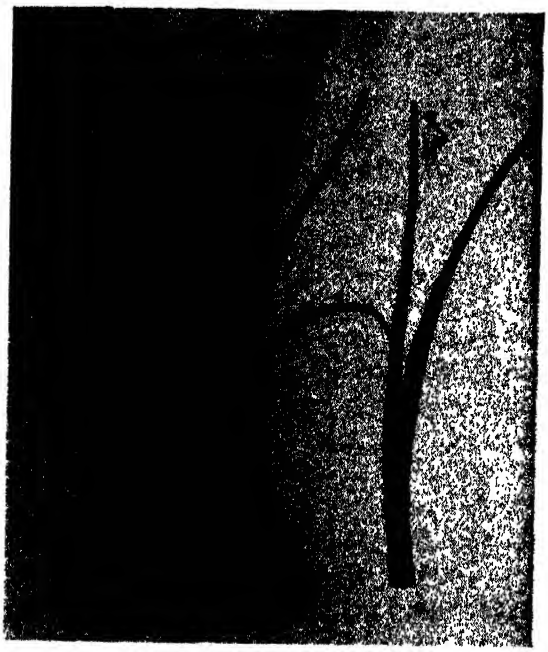

FIG. 8. Taro stalks as they are sold in Oriental markets of Hawaii. The petioles of all varieties, especially of dasheens, constitute a favorite food of the Orientals, and are diced and fried with meat or boiled as greens. (*Courtesy Hawaii Agr. Exp. Sta.*)

sun-dried raw corms and ground them in a hand mill. In 1874 scraped taro was furnace-dried. Still later in 1886 the last Hawaiian king, Kalakaua, subsidized the taro flour industry to encourage exports to other countries. By the time of the present experiments more than $66,000 was lost in attempts to produce and market taro products.

In 1935 a leader in the search for new taro uses was Gaston J. Ley. He investigated varieties of taro which would make the best flour, and sought to improve production methods in poi factories as well as to discover all possible uses for taro which would be commercially feasible. Through his work it was learned that taros which make the best poi also make the best flour. Dasheens, or Oriental taros, which do not make good poi, were found to make unsatisfactory flour. It was also discovered that pre-cooked taro is better than raw corms. Through various ways of drying cooked taro different products can be made. These can be varied by adding flavoring or skim milk either before drying or afterwards. Tray drying was found best for flour and cereals, drum drying for beverage powders. Taro corms were canned and found to be unchanged and as palatable as fresh cooked corms.

Mr. Ley decided that by using the scientific and practical discoveries made from his experiments he could successfully start a factory making these various taro products. In March of 1937, with the financial backing of several prominent Honolulu men, Hawaiian Taro Products, Ltd. was founded and went into production on an experimental basis. The initial capital was $60,000, and the capital limit $1,000,000. The factory was located in the midst of good taro-growing land, and very near transportation facilities. Flour was made in quantities of one ton daily. Beverage powders and cereals were made in smaller quantities. These products were sold both locally and in the continental United States. However, on the advent of war, the company was forced to shut down. Now under new management, this factory is beginning again, this time on a larger scale, as the products have proved their worth.

These goods consist of flour, or "Poyo-Meal", as it is called for mainland sale; "Taro-Lactin", or "Poyolin", a taro

flour-skim milk infant food; and "Taro Malt", or "Poyo-Malt", a plain or chocolate-flavored malt beverage powder. Before the war they could be found in Honolulu markets and drug stores, and on the mainland in health food stores. Now, due to extremely limited production, one must write to the company for these products.

Two more Hawaiian companies can poi mainly for local consumption, and there are numerous factories, mostly small, which produce fresh poi for local consumption.

Several other products have been tried in the past with more or less success. The most popular of these were thinly sliced pink-cormed or colored-fiber corms fried in deep fat. Both their flavor and attractiveness made these taro chips much in demand. Their manufacture was discontinued during the war, but will no doubt be revived when more taro is produced.

Two types of breakfast foods attempted by the experimental company were dry shreds and a grit which could be eaten dry or cooked. Although these were palatable they were unable to compete successfully with already established cereals. In 1888 the same fate had accompanied an attempt to make macaroni and crackers. Dried poi has constantly been tried in the islands, but has never been a commercial success.

U. S. Taro Products

In the continental United States a few attempts have been made to manufacture raw dasheen flour, also without success. At present we do not know of any company doing this work. Dasheen sprouts are forced in greenhouses in Florida as a winter crop, and when cooked like asparagus, the shoots have a flavor reminiscent of mushrooms.

Experiments have shown that taro starch has possibilities for sizing textiles, but due to a gummy substance present in all taros, commercial production might be impossible unless a cheap and easy way could be found to remove the gum.

Production Problems

Today, as in the past, many major obstacles are encountered in the Islands in producing taro and its products. The first important problem is the creation of a ready market. Because of their familiarity with the plant, Island people in all economic brackets eat taro or poi frequently in conjunction with or as a substitute for rice and potatoes. In fact, the demand for poi is so great that not enough taro is grown to supply the factories or to supply the markets with corms for table use. When corms are found they are attractively sold in the old Hawaiian type of bundle, four corms tied together with the petioles attached.

Dasheens are more common. They are peddled in vegetable wagons, or sold by the pound either whole or peeled, submerged in jars of water where they are kept until used. As dasheens are Oriental taros they are most frequently eaten by the Japanese and Chinese. In 1945, there were only 18 acres under cultivation which supplied the market fairly well. Those Orientals who have a little land invariably grow their own dasheen crop.

Taro leaves, or luau, are found occasionally at native markets, and when desired in quantities can be ordered. The cooked greens are preferred to spinach. Orientals have a preference for taro petioles, either green or blanched, and these are available solely at Oriental markets or vegetable wagons.

Medical Value

The local people of Hawaii have long been hesitant to try dried taro products, primarily because such products are different, but through the aid of local physicians the people are gradually becoming familiar with them and enjoying their

flavor. Taro-Lactin is now a regularly prescribed infant food and can be fed to a newborn baby almost immediately, according to the doctor's formula. Patients suffering from ulcers and other alimentary disorders, or convalescents, derive great benefits from this easily digested, nutritive food. It is also recommended strongly in pre-natal diets as well as for nursing mothers. Taro flour is prescribed to cereal allergy sufferers.

Flour

Taro flour is frequently used in Honolulu bakeries to make a wide variety of breadstuffs. Its properties are very similar to those of potato flour, and the flour must have the same handling; its range of possible combinations, however, is wider.

Taro bread is the most widely sold product of taro flour. Besides its distinctive color and flavor, taro bread, containing 15% taro flour and 85% wheat flour, stays fresher than ordinary bread because of the moisture-absorbing properties of taro. Cakes, cookies and doughnuts taste better when made with this flour. Because taro does not contain the glutinous properties of wheat, taro flour makes excellent thickening for gravies and puddings, as they will not become rubbery.

Experiments have shown that all varieties of taro make similar flour. Therefore, when more taro can be grown commercially, flour will probably be classified as grey, pink, yellow or white, depending on the variety, and each can be used for different food products. At present the color of taro is one of its greatest handicaps. Few foods are so variously colored. Because the most important commercial varieties are pink cormed, all dried products range from pink to salmon color. This will create one of the greater problems in educating the non-Hawaiian market to use these products.

Acreage

Once the public has become familiar with the products of taro and wishes to buy them, the farmers of Hawaii will have to plant more acreage. At the time of this writing there are only 804 acres of both wet and dry land taro grown in Hawaii, not including dasheens. Although an acre of wet taro averages 12 tons of harvested corms, and dry taro ten tons, one must remember that this crop can be harvested only once, nine to 19 months after planting, depending on the variety. The farmers, who are for the greater part Chinese and Japanese, like all farmers, want to make money. With taro land rentals excessively high and the present wholesale price of taro about $.03 per pound, the farmers would rather grow other truck crops which bring in more money per crop and which can be harvested every four months instead of every twelve.

Labor

Moreover, wet taro culture is a tedious, filthy job. With the changing social conditions among the Orientals the younger people, if they must farm, prefer cleaner work. Their predecessors came from rice-growing lands and continued to grow rice in abandoned taro patches. With the gradual decline in local rice production these lands either became pastures or reverted to taro which then had a good market. Gradually another shift is taking place to accommodate the new social change. More and more taro is being grown under dry land conditions which is similiar to other truck gardening. Before many more years go by, provided there is an increased demand for taro products, one will see wet taro only in small isolated communities.

Diseases

Another factor in the change from wet to dry culture is the higher prevalence

of disease in lo'i. The old Hawaiians spaced their taro far apart and insured a steady stream of cool water through the plot, carefully tending the plants before their roots were well established. Today, with money-making the foremost idea, the farmers crowd their plants, crop after crop, with the result that the whole field usually is wiped out by disease or by worn-out soil.

Wet taro is heir to more hazards than dry. Two rots cause the most serious damage. An unidentified Pythium rot causes the corm to become mushy and malodorous. The other is a hard rot, the cause of which is still unknown, since no definite organism has been identified. Both of these rots can be controlled by planting healthy huli from taros known to be resistant to the disease, in rotating or fallowing fields, and by insuring a circulating current of fresh water through the lo'i. Great losses are caused also by a leaf spot (*Phytophthora colocasiae*). No taro is resistant to it, but it can be controlled by planting huli 30 inches apart and by growing the plants in a cool, dryish location free from constant strong winds. Contrary to popular opinion, taro does better in a climate which has a temperature not far above or below 70 degrees Fahrenheit, and which is not too humid.

Other problems not caused by disease or poor agricultural methods are few, but have caused serious loss. Several years ago a crayfish (*Astacus nigriscens*) was introduced as frog feed, but these escaped through waterways to lo'i where they not only destroyed roots but bored holes through dykes, causing leaks. By constant treatment of the water with pra-radi-chloro they can be controlled. On April 1, 1946 many coastal taro fields were destroyed or damaged when a tidal wave inundated them. The lo'i were immediately repaired and the taro replaced without excessive loss.

Upland, or dryland, taro, besides being easier to cultivate, is either immune from or highly resistant to diseases common in the lo'i. A leafspot (*Phyllosticta* sp.), a root rot (*Sclerotium Rolfsii*) and nematodes cause a nuisance, but are of small economic importance. Sufficient irrigation and the above cultural precautions are used to control them. As dryland taro is usually grown at from 1,000 to 2,500 foot elevations in rich, humus soil, climate other than an insured rainfall of 70 inches is of small importance, as the temperature at these elevations is always cool during part of the day. However, with the growing importance of dryland culture for wetland varieties, the farmer must keep in mind the necessity of a cool climate.

Harvesting

Harvesting is accomplished in both wet and dry fields by hand pulling. The huli are cut off, the corms roughly washed and put into gunny sacks which hold about 100 pounds. With greater production a harvester, similar to a potato harvester, could be more profitably used, but at present hand pulling is satisfactory.

Poi

As most poi factories are situated next to the taro fields, transportation is of small importance. One exception to this is in Waipio Valley on the island of Hawaii. Waipio is one of the oldest and largest taro-growing communities and is extremely primitive. To get in and out of this deep valley one must walk or ride down a steep cobblestone road. One of the picturesque sights to see is the weekly cavalcade of pack mules loaded with large packages of paiai (dried poi) wind up the trail to the town on the brow of the cliff.

At the poi factory, usually a one- or two-room cement building, the corms are steamed under pressure as they come from the field. They are then peeled and trimmed by hand and are ground into paiai. Next, the paiai is mixed with suf-

ficient water to comply with the local pure food regulation that poi should contain at least 30% solids. It is then set aside in barrels to ferment from one to five days. Frequently a "starter" of poi is used to insure proper fermentation which is brought about by five common soil bacteria[1] that are not killed during the cooking process.

Occasionally this regulation is "complied" with by adulterating the poi with flour when taro is scarce. Other adulteration is carried out by adding pink food coloring to make common grey poi look like the choicer red poi. These practices are fortunately not often found today, although they were once quite common.

Poi is sold directly from the factory, where people queue up in long lines when it is on sale. It is sold in white cotton sacks containing about two pounds, and sells for $.20 a pound. Before the war a bag containing about five pounds sold for $.25. In rural areas a truck delivers poi to houses wanting it, where a white flag, called "poi flag", has been raised by the front gate.

Dried Products

The dried taro products factory must go through the same preliminary steps as a poi factory, except that no fermentation takes place. The paiai is refrigerated for 36 hours so that the stickiness peculiar to taro is eliminated. Chunks of refrigerated paiai are then shredded by machinery. The next step depends on the product desired. If it is to be flour or breakfast grits it is tray-dried. If it is to be beverage powder it is mixed with water and flavoring and drum-dried. "Taro Lactin" is sealed in No. 2½ tins because of the present taro shortage, but is soon to come out again in its pre-war ten-pound can. Taro flour is today sold in ten-pound tins but formerly was dispensed in 100-pound sacks for bakeries and hospitals.

At present there are only three companies which make enough poi for canning, and only one of these has a large enough supply to export. This last company, Hawaiian Foods, Ltd., formerly Hawaiian Taro Products, Ltd., is the only one making dried taro products.

The future of taro production in Hawaii is uncertain. The crux of the situation rests with the public: if they know about taro, do they want to eat more of it and its products? If they don't know about it, are they willing to give it a fair trial? The Hawaiian Foods, Ltd. is about to launch a trial balloon to find the answers to these questions. If they are successful in their endeavor, a new major industry will be developed in Hawaii and might be an impetus to California and to the southern States to seriously grow dasheens for commerce, as it has been proven that these States are well suited to its culture.

Summary

Taro roots figuratively reach back into history. Taro, in its various forms, has been grown throughout large sections of the world for more than 2,000 years. It was a familiar and important food crop in India, Malaysia, China and Japan when Pliny first saw it growing in Egypt. Egyptian taro was sent to Rome, whence it spread to Portugal and to marshes in Mediterranean islands. About 200 years ago taro even found its way from China to Sweden, where it was displayed as a hothouse curio. Negro slaves from French Tropical Africa grew taro for the first time in the earth of the New World.

While taro, in its many forms, was being carried about and cultivated in Africa, Europe and Asia, it was also putting its roots into marshes and mountain lands of countless Pacific islands. The

[1] *Lactobacillus delbrucki, L. pastorianus, L. pentoacetícus, Streptococcus lactis* and *S. kefir.*

daring Polynesian seafarers, moving across the great Pacific Ocean in double canoes, searching for and settling on new island homes, carried with them their staff of life, the taro plant. To this day taro is still the most important food in the diet of many Pacific natives.

It is worthy of mention, in summarizing the history of taro, that this interesting and healthful crop, though cultivated and eaten by millions of people throughout the centuries, has never had great commercial value. Almost without exception taro has been eaten only by those who cultivated it.

It is highly possible that today a new chapter in taro history is being written. Within the next few years taro may finally come into its own as an important commercial food crop.

Utilization Abstracts

Sesame. Since ancient times the seeds of sesame, *Sesamum indicum* of the Pedaliaceae, have been a very important source of vegetable oil in China and India. "In many parts of the world the seed is well known as an adornment on bread and rolls. To a lesser extent it is used in candy and in a refreshing drink called *horchata*. The oil, usually pale yellow when refined, is used as a salad and cooking oil and as a component in the manufacture of margarine, shortenings, and soap. Sometimes it is mixed with olive oil as an adulterant. Small quantities of sesame oil find outlets in the pharmaceutical and perfume industries. In some countries the oil is still used as an illuminant.

The leaves, when submerged in water, form a mucilage-like substance used in treatment of diarrhea and dysentery. The pressed cake makes an excellent livestock feed, containing from 10 to 20 percent oil, depending upon the method of extraction and conditions of growth".

China has long been the principal producer of the seed, and in recent years has supplied about half the world total, with India supplying about one third, and Latin America and Africa the remainer. In 1945 world production was estimated at nearly a million and a half short tons of seed, and of this quantity about 100,000 tons were grown in Latin America.

The plant, of tropical and subtropical regions, is an annual, originally from Africa, and grows two to five feet tall, producing oblong seed pods about 1½ inches long containing about 80 seeds each. The oil content of the seed varies from 45% to 55%. Harvesting begins 110 to 140 days after planting and is performed by hand cutting or machine mowing. The seeds are obtained by threshing.

Sesame is the largest single source of vegetable oil in Mexico where close to 90,000 short tons of seed were produced in 1945 and where the oil is normally used for edible purposes, secondarily in soap manufacture. In that country hydrogenated sesame oil is reported to be popular with the baking trade as a lard substitute. In Nicaragua, too, it is the most important source of vegetable oil. In the 1942–1943 season about 4,500 tons of the seed were produced there, much of it being sent to the United States. In Colombia production reached a peak of 6,800 tons of seed in 1943. In Venezuela 3,300 tons of seed were produced in 1944. Brazil, Peru, Ecuador and other countries of Latin America produce smaller amounts.

In the United States only experimental plantings have been made in the South, in California and in Arizona. During 1935–1939, previous to obtaining the seed from South America, about 27,000 short tons were annually imported, primarily from China and India. (*D. E. Farringer, Agriculture in the Americas 6: 160. 1946*).

Brazilian Timbers and Medicinals. The Brazilian Government Trade Bureau issued in 1946 the following two pamphlets of about 20 pages each: "Timber in Brazil", "Medicinal and useful plants in Brazil".

Veneers and Plywood—*Their Manufacture and Use*

Two closely related industries that depend, to a major degree, upon domestic sources of red gum, Douglas-fir, black walnut, red and white oaks, sugar maple, Sitka spruce, Ponderosa pine and Port Orford cedar; and upon foreign sources of mahogany, rosewood, zebrawood, avodiré, bossé, ebony and other exotic species.

ELLWOOD S. HARRAR[1]

Definitions and History

VENEERS are thin sheets of wood of uniform thickness produced by sawing, peeling or slicing logs, bolts and flitches. "Plywood" is a trade term applied to composite wood panels composed of an odd number of sheets of veneer bonded together with a suitable adhesive in such a manner that the grain of each adjacent layer lies at right angles to that of the next. The simplest panel is a 3-ply member consisting merely of face, core and back plies. In panels comprised of five or more layers of wood, the grain of the face, core and back plies parallel one another; the alternate sheets are known as crossbands (Fig. 1). The term "plywood" is applied commonly also to panels in which a lumber core of some predetermined thickness is used in place of the conventional veneer core. "Laminated wood" is not to be confused with "plywood", although these two terms are not infrequently used synonymously. In the restricted sense, a laminate is a multi-ply panel or structure in which the grain of all layers parallel one another.

The art of veneering is nearly as old as civilization itself and actually antedates the birth of Christ by more than 1,500 years. Exquisitely designed and skillfully fabricated pieces of plywood furniture, found in the tombs of the Pharaohs, give silent testimony to the dexterity and artistry of the ancient Egyptian cabinet makers. A number of the essential features of a modern plywood panel were found in the headboard of a bedstead reputed to have belonged to the grandparents of Tutankhamen's wife. Made of laburnum wood and lavishly embellished with gold and precious stones, it was as sound as though it were made but yesterday. How the wood was cut into thin, delicate sheets of veneers, or what was the nature of the adhesive that stood the tests of 35 centuries, is a story yet untold.

In the years that followed, Assyrian, Babylonian and Roman craftsmen, influenced by the Egyptian stylists, made several significant advances in the use of veneers in cabinetry. The Romans developed the art of matching figured veneers to produce unusual decorative effects as well as beautiful patterns of warmth and charm. In his "Natural History," Book XVI, Pliny revealed that the root-wood of certain species was often used, thus indicating that the ornamental value of stump and root-wood has long been recognized. He also recorded that among the many personal treasures of Julius Caesar, the one held

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in highest esteem was a beautifully veneered table.

During the Middle Ages and early Renaissance, oppressive ecclesiastical and political orthodoxy effectively stifled all creative thinking, cultural interests and practice of the arts. Toward the end of the latter, however, a revival for learning became manifest, and in the years that followed, some of the world's finest masterpieces in sculpture and painting were created. Interests in wood-working and marquetry were also re-born, and in 1769 Riesener completed his "Bureau du Roi" for Louis XV, said by many in authority to be the finest specimen of veneered furniture of all time. The eighteenth century also witnessed the peak in period stylings and with it the creations of such renowned craftsmen as Duncan Phyfe, Hepplewhite, Chippendale, Sheraton and the Adams brothers.

Until the middle of the nineteenth century the finest furniture was hand made, and into each piece went all the skill, ingenuity, artistry and pride of the master. Quality, not quantity, was his watchword. The work was slow, painstaking and laborious; the furniture costly and available only to the wealthy.

About 1840, furniture manufacturers began to mechanize their shops in order to produce goods on a mass production basis. In some of the shops quality was readily sacrificed for quantity. Ornate inlays and a variety of highly figured veneers were applied over poorly fabricated structure merely for the purpose of concealing shoddy workmanship. Eventually this practice adversely affected the sale of all veneered furniture because buyers began to regard such merchandise as an inferior substitute for comparable articles constructed of solid lumber. This concept is still held by many uninformed, even in these modern times, and our leading dictionaries do little to dispell this view, defining veneer as "a layer of more valuable or beautiful material over an inferior one."

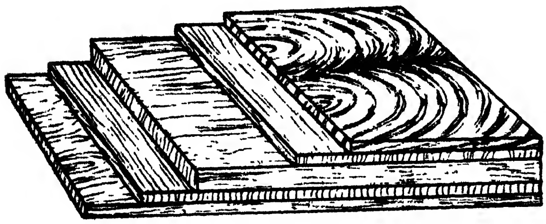
Veneering as practiced today needs no defense, but rather an intelligent understanding of the purposes and advantages of veneered construction. Engineers, wood technologists, chemists and designers have combined their knowledge and skills to produce a superior wood. This is plywood. How it is made, its advantages over solid lumber, and its many uses will now be reviewed.

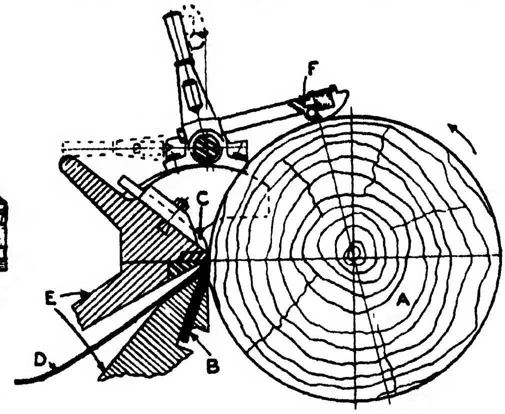
Manufacture of Veneers

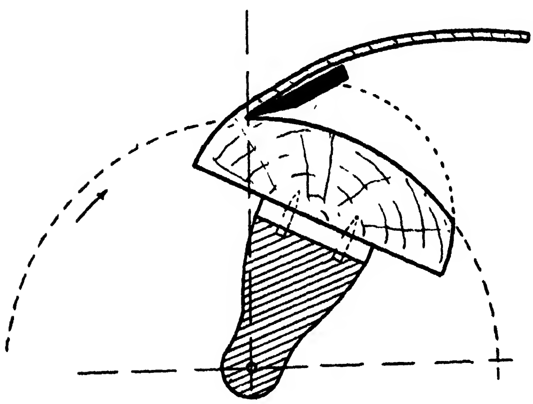
There are at present five methods employed in the manufacture of veneers. Prior to the twentieth century, veneer logs were first cut into flitches[2], and the flitches in turn were cut into thin sheets of wood by driving them against a circular saw. This was both an expensive and wasteful procedure, since much of the best and clearest wood in a log was removed as slabs, and more than half of the potential veneer in the flitches was reduced to sawdust in the sawing operation. In more recent years rotary lathes and slicers have all but replaced the veneer saw, and today less than 5% of all veneers manufactured in the United States are sawn.

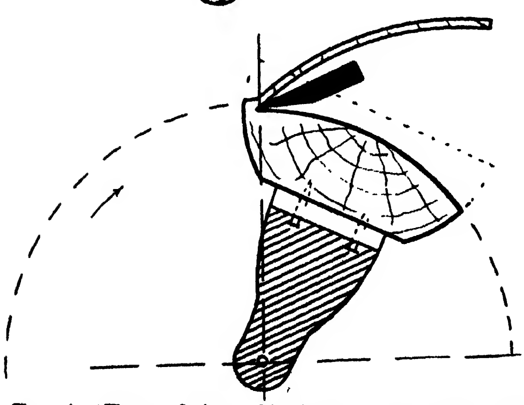
Rotary-cut Veneer. At present nearly 90% of all veneers manufactured are rotary cut. In this process a bolt of wood of predetermined length is held by two chucks and centered on a massive lathe. When in place the bolt is slowly turned against a stationary knife extending across its length. Figure 2 is a diagrammatic sketch of the modern lathe. The bolt (A), turning in a counter-clockwise direction, strikes the knife (B) and a pressure bar (C) which holds the wood firmly at the instant of cutting. The knife carriage (E) automatically moves the knife into the revolving

[2] A flitch is a longitudinal segment from a log.









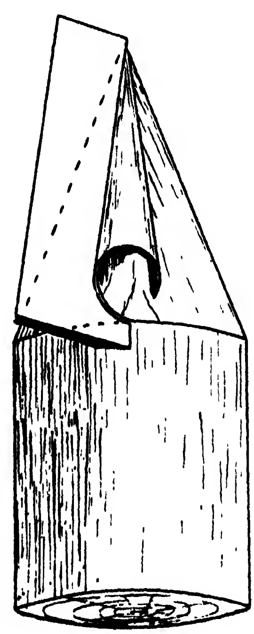


FIG. 1 (*Upper left*). Typical 5-ply panel construction. FIG. 2 (*Upper right*). Diagrammatic sketch of a modern veneer lathe. FIG. 3 (*Center left*). Diagrammatic sketch illustrating stay-log cutting. FIG. 4 (*Lower left*). Diagrammatic sketch illustrating back cutting. FIG. 5 (*Lower right*). Diagrammatic sketch illustrating cone-cutting.

bolt at a given speed, thus controlling the thickness of the sheet. The resulting veneer (D) is led out through a slot in the knife carriage. In rotary cutting, a bolt is literally unwound (much as one might unroll a bolt of wrapping paper), and the veneer is produced in a long, continuous ribbon of wood (Fig. 6). Giant lathes capable of peeling whole logs 12 to 16 feet in length are used by a few manufacturers. More commonly, however, logs suitable for the manufacture of veneers are sawn into peeler-bolt lengths of from 24 inches to 8 feet and turned on smaller, faster lathes.

The surfaces of veneers, to be suitable for gluing, must be clean and smooth. Experience has taught the producer that

a better sheet is obtainable from woods of moderate density if the bolts are first steamed or steeped in boiling water for several hours before they are peeled. Some of the softer, low density woods, such as basswoods, yellow-poplar, Douglas-fir, spruce and cottonwood, produce better veneers if they are "cold-cut", since fuzzy, fibrous veneer surfaces are not unusual if the wood of these and similar species is subjected to preparatory heating. When bolts are heat-conditioned the bark is ordinarily removed after the cooking process.

Rotary veneers are manufactured into thicknesses ranging from 1/40 to 1/4 inch. The thicker veneers (1/8″ and up), if unrestrained, have a tendency to assume the peripheral curvature of that part of the bolt from which they are cut. When flattened the upper surface is under compression and the lower face is in tension. As a result of the tension stresses set up, numerous minute checks and cracks develop in the lower face. Veneers of this sort are said to be "one-face" veneers. The face in compression is called the "tight side", the other, the "loose side". When one-face veneers are used for face and back plies of plywood panels, the loose side is always on the glue line. In producing thinner sheets it is possible to cut them without the subsequent development of checks in the lower surface. Veneers of this sort are termed "tight-cut". Tight-cut veneers are more readily produced when excessive pressure is exerted by the pressure bar. If the pressure is intentionally relaxed, the fibers in the wood are easily ruptured and "loose-cut" veneers result. Loose-cut veneers have much less tendency to bow than do tight-cut sheets. To aid the manufacturer in keeping track of the tight side of veneers throughout subsequent operations, a scribing device on the lathe (Fig. 2, F), a pencil or crayon, marks the sheet as it is cut. This mark may be sanded out or trimmed off later in the finishing of the plywood panel.

Rotary cutting is the cheapest means of producing veneers, and the bulk of the veneers cut in this manner are of the commercial variety. Commercial veneers are those which are used largely in the fabrication of articles where strength rather than figure is of primary concern. However, the lathe is a versatile tool, and many types and grades of veneers ranging from coarse, cheap materials used for berry boxes, citrus crates and egg cases, to the expensive and highly figured face veneers of black walnut, bird's eye maple and tamo[3] used in cabinetry are rotary cut.

When a ribbon of rotary cut veneer leaves the lathe it passes over a series of table rolls which conveys it to a clipper or guillotine. Here major defects are cut out and the ribbon clipped into veneer sheets of standard widths. After sorting and grading the sheets are ready to be dried.

Stay-log Cutting. This is merely a modification of rotary cutting and is used primarily for the production of fancy face veneers cut from longwood,[4] burls, stumps and crotches.

A stay log is merely a long, flanged, steel casting mounted on eccentric chucks in a conventional lathe. A section of longwood (flitch) or other material is securely fastened to the stay log by short, heavy lag screws inserted through pre-drilled holes in the flange (Fig. 4). Longwood mounted and cut in the manner illustrated (Fig. 4) is said to be "half-round cut." Since the operator may change the radius of the swing of the stay log at will, it is possible to enhance the figure of such sheets. Stay-log cutting also permits manufacture of wider sheets of veneer than is ordinarily possible in the conventional slicing operation to be described. Fig-

[3] Japanese ash.

[4] Flitches from a log or bolt.

FIG. 6 (*Upper*). Rotary peeling. *Courtesy Wood Mosaic Co., Louisville, Ky.* FIG. 7 (*Lower*). Slicing a mahogany flitch. (*Courtesy Mahogany Association, Inc., Chicago.*)

ure 9 illustrates a typical "black-cut" stay-log operation. Back-cut veneers obtained from stump-wood and crotches are usually handsomely figured (Fig. 12), but care must be exercised in handling them. Fiber alignment in materials of this sort is very irregular. In consequence, much fiber is cut across rather than along the grain, and the resulting sheets are apt to be brittle, particularly when there is an abundance of "short-grain".

Cone-cutting. Cone-cut veneers are circular sheets of veneer made by taper-peeling a bolt (Fig. 5), in a manner similar to sharpening a pencil. The contact angle of the knife determines the degree of taper, the approximate width of the sheet for a bolt of given diameter, and the number of revolutions the bolt must take to produce a complete circular sheet. Veneers made in this way are "short-grained" and hence are apt to be brittle. However, they usually possess beautiful stellate or "wheel" figures and are used in the fabrication of panels for fancy circular table tops.

Sliced Veneers. Veneer slicers were developed in an effort to eliminate the wasteful practice of sawing. With numerous improvements of the original slicing device, most of the figured woods that were formerly sawn into face veneers are now cut on slicers. While slicers can be used to produce veneers of all types, they are largely used only for figured woods for face stocks.

Sliced veneers are usually cut in log lengths of from 12 to 16 feet, although cutting is by no means restricted to such limitations. Logs to be used for the production of sliced veneers are first halved lengthwise on a circular or band saw, and then not infrequently cut into smaller flitches at the option of the producer. An experienced and skilful operator is usually in charge of preparing the flitches. Upon inspection of an opened log he must be able to visualize the hidden figures it possesses, and to indicate how it is to be flitched in order that these figures may be brought out in the veneers subsequently cut. If in his judgment radial slicing is desired, the half-log is further reduced to six or eight flitches for the production of quartered-veneers, *i.e.*, the slicing plane is parallel to the wood rays and at right angles to the growth rings. If, on the other hand, "flat-cut" veneers[5] are to be sliced, no further flitching is ordinarily required. Before the actual slicing operation begins, it is necessary to tenderize the logs and flitches in steam or hot water vats in a manner similar to the treatment of bolts for rotary cutting.

A vertical slicer is most commonly used in the veneer plants of the United States. In practice a flitch is firmly "dogged" to a heavy metal bed plate fastened to two angling slides set in a heavy metal frame. The flitch is driven down against a pressure bar and knife, and the resulting sheet passes out through a slot in the knife carriage (Fig. 7), similar to that on the rotary lathe. On the up stroke the knife carriage moves forward and thus is in position to slice off another sheet with the next cutting stroke. The angling slides give the flitch a slight lateral movement as it travels toward the knife. This makes for smoother veneers, since the cutting action is somewhat along the grain of the wood rather than directly across the fibers. Such a shearing action is particularly helpful in producing smooth surfaces when woods with curly, wavy or interlocked grain are sliced.

When slicing face veneers, the sheets from a given flitch are turned over as they come from the knife and stacked consecutively, exactly in the order cut. Such a bundle is also called a "flitch", and in subsequent handlings it is re-

[5] Flat-cut veneers are made by slicing half-sections of logs. Both quarter-grained and flat-grained figures are then commonly present in the same sheet.

FIG. 8 (*Upper*). Battery of veneer segment saws. FIG. 9 (*Lower*). Walnut stump being cut on stay-log. (*Photos courtesy Wood Mosaic Co., Louisville, Ky.*)

garded as a unit; especial care is exercised to preserve sheet sequence at all times. The reasons for this will be explained later.

Sawn Veneers. In these modern times but little veneer is produced by sawing. Ordinarily sawing is restricted either to woods of cabinet rank that are highly refractory and unsuitable for slicing (ebony, satinwood, knotty eastern red cedar), or to those that cannot be tenderized in cooking vats without impairing their color. Woods with appreciable tannin are commonly sawn, since hot tannin extracts coming in contact with a knife impart objectionable iron tannate stains to the wood.

The modern veneer saw is known as a "segment saw" (Fig. 8). It consists of a heavy metal, tapering flange (mounted on an arbor) to which are bolted several thin, saw-steel segments along its periphery. In this way the kerf is considerably less than that of a conventional circular saw blade of similar size. Despite this, about half of a flitch is reduced to sawdust in the production of 1/20″ veneer.

Sawing a sheet of veneer differs little from the conventional method of sawing a board. A flitch, prepared in the usual manner, is fastened securely with timber dogs to a carriage and then driven into the whirling blade. When the saw has passed through the flitch, the carriage returns to its former position, moves forward a distance equal to the combined thickness of a sheet and saw blade, and the cutting operation is then repeated.

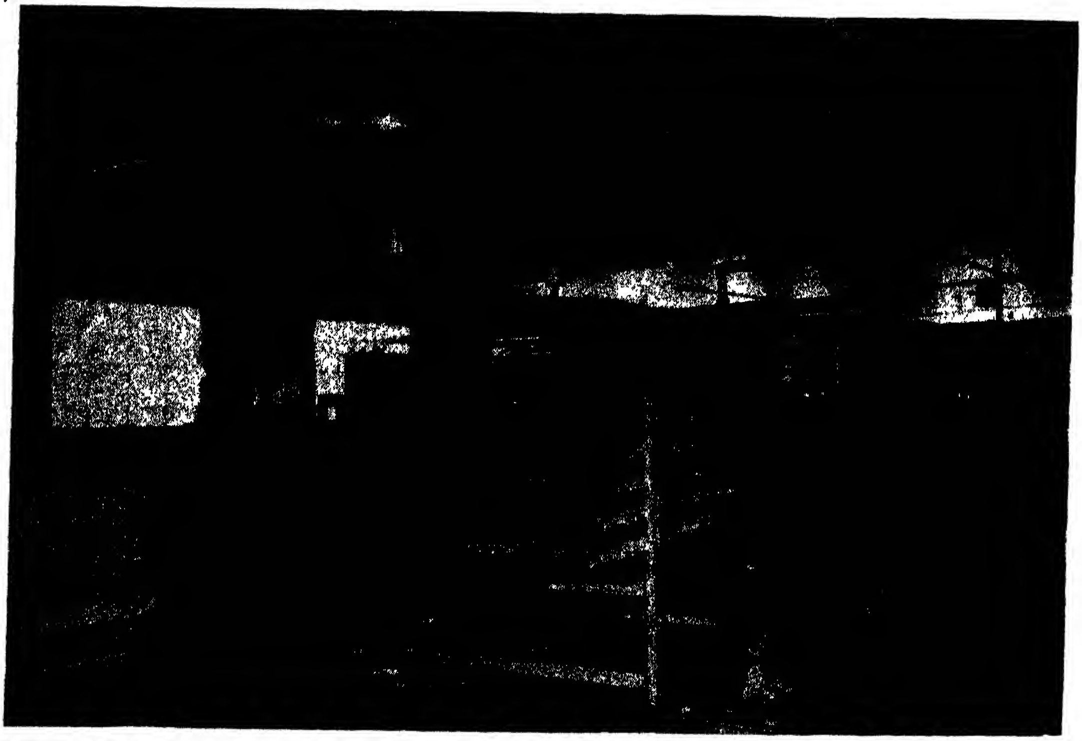
Port Orford cedar and basswood slats for venetian-blinds, and cedrela shook for the manufacture of cigar boxes are also commonly made with a segment saw.

Veneer Thicknesses. Veneers are cut in a wide variety of thicknesses, ranging from 1/110 to 3/8 of an inch. Most of the rotary veneers are 1/7″, 1/8″, 1/9″, 1/10″, 1/16″ or 1/20″ thick. Sliced veneers usually range from 1/20″ to 1/40″, but the bulk of face veneers so cut are either 1/20″ or 1/28″ in thickness. The very thin sheets of cedrela (Spanish cedar, *Cedrela odorata*), used to wrap individually fine cigars, and some other speciality veneers are often only 1/100″ to 1/110″ thick. During World War II, 1/64″ mahogany veneers were used in the manufacture of wing-skins for aircraft. Sawn veneers vary from 1/4″ to 1/32″ in thickness, with 1/20″ stock being the most common.

Veneer Drying. Freshly cut veneers are ordinarily very wet, and in that condition are wholly unsuited for gluing. Moreover, they are readily susceptible to the attack of molds, blue stain and wood-destroying fungi. Thus it is necessary that excessive moisture be removed from them as rapidly as possible, consistent, of course, with good drying practices. Exception to this general rule may be found in the basket industry. Since wood is much more pliable when it is wet, it may be bent to much sharper curvature without danger of rupture. Hence the basket weaver commonly works with wet veneers, and dries them only after the product is fabricated.

Several methods for drying veneers are in common use. The selection of one of them for any given plant is usually dependent upon the ultimate use of the stock and the facilities available to the manufacturer.

1. *Air drying.* The cheap grades of rotary (and occasionally sliced) veneers used for fruit and vegetable crates, egg cases and packing case materials are sometimes dried in the open. In such instances they are dried merely enough to prohibit the growth of fungi and to reduce shipping weight. When air drying is practiced, the sheets are laid between tiers of stickers, or loosely stacked on end in finger racks in order to permit free circulation of air over their surfaces.



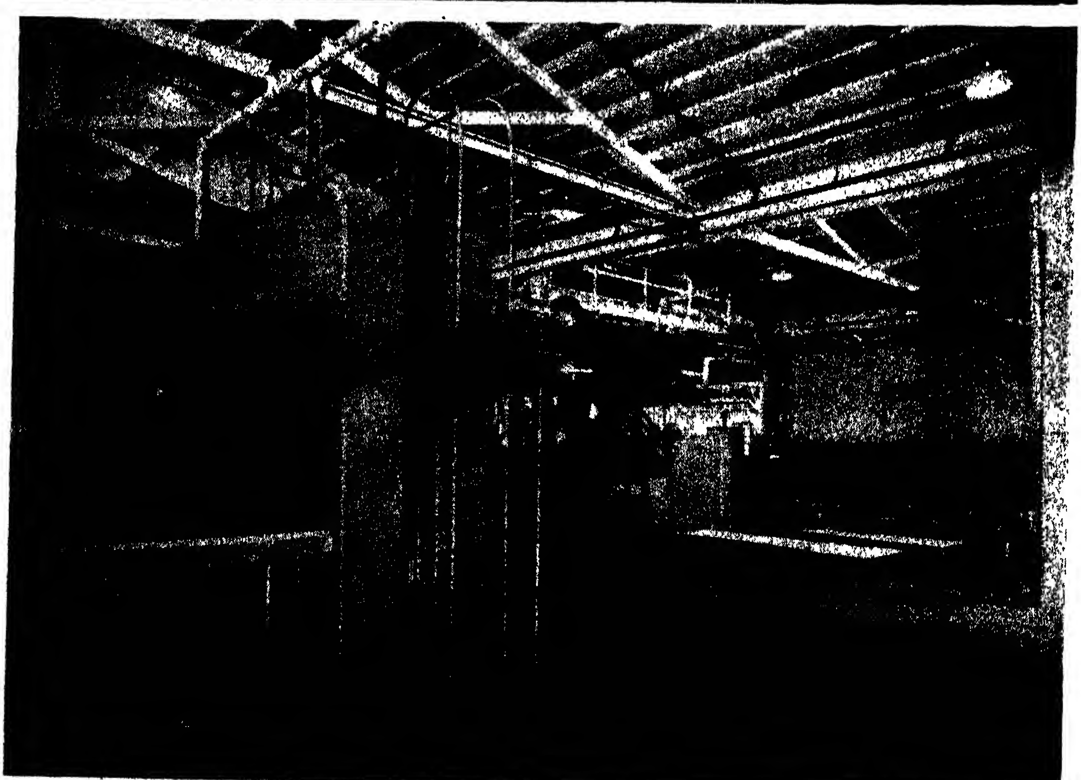


FIG. 10 (*Upper*). Roller type, five-deck conveyor drier. FIG. 11 (*Lower*). A modern plywood hot press. Wet lay-ups are fed in from the left and the bonded panel is removed from the back of the press upon completion of the bonding cycle. (*Photos courtesy Merritt Engineering & Sales Co., Inc., Lockport, N. Y.*)

2. *Loft drying.* A loft is merely a well ventilated room, with or without humidity control. Wet sheets of veneer are hung on clips from rafters or edge stacked in finger racks. Here they remain until the moisture content stabilizes at 12% to 15%. In thin sheets of the order of 1/20″ in thickness, only a day or two is required to bring the moisture content down to within these limits if suitable drying conditions prevail.

3. *Kiln drying.* The conventional, progressive type, lumber dry kiln is also used in drying veneers. In practice several sheets are bulked between each tier of stickers. One plant in North Carolina producing 1/8″ rotary red gum veneer bulks 10 sheets between stickers and dries them to a moisture content of 6% in 48 hours.

4. *Veneer driers.* At the present time most veneers are dried in carefully designed and engineered devices that permit rapid and uniform drying without adversely affecting the sheets. Two types of such equipment, namely, conveyor driers and hot-plate driers, are in common use.

Conveyor driers are chambers 50 to 100 feet or more in length, fabricated of sheet metal and suitably provided with heating equipment, and two to six paired banks of power-driven rolls or belts to move the veneers longitudinally through them (Fig. 10). The rapidity with which veneer passes through driers of this sort is dependent upon numerous variables such as original moisture content of the wood, manner in which veneers were cut, veneer thickness, degree of dryness required, and efficiency of the drier itself. Rotary cut 1/8″ sweetgum veneer may be dried to a moisture content of 4% to 6% in 13 to 16 minutes in driers of this sort.

Hot press driers consist of a bank or battery of heated platens. Sheets of veneer are placed on the upper faces of the platens that are then brought together to keep the sheets flat while drying. During the drying interval the platens are intermittently opened and closed to allow moisture to escape as it is driven from the wood. Driers of this sort are very efficient but have a smaller capacity than the conveyor type. However, when floor space is at a premium they are to be preferred.

The Veneer Industry. A large variety of woods, both foreign and domestic, are utilized in the manufacture of veneers, but more than one-half of the total annual American output is comprised of red gum and Douglas-fir (*Liquidambar styraciflua* and *Pseudotsuga taxifolia,* respectively).

Hardwood veneer manufacturers are widely scattered throughout eastern United States, although there are a few plants on the West Coast. These manufacturers are divided into three categories, according to the kind of veneer they produce.

1. *Face-veneer manufacturers.* These usually limit their activities to the production of sliced, sawn or stay-log cut fancy face veneers from carefully selected logs, burls, crotches and stumps. Such materials are usually handsomely figured and are used as facings for plywood panels employed in the fabrication of furniture, pianos, cabinetry, and for interior decorative paneling.

There are more than 50 manufacturers of face veneers scattered through the Ohio and Mississippi River valleys and adjacent territories, the Lake States and in larger cities along the Atlantic seaboard.

The manufacturer of face veneer cuts his raw materials as received and builds up sizable inventories which are stored in well ventilated warehouses. After each flitch is dried and bulked in sheet sequence it is given an identifying number. One or more samples are then removed from each flitch. A sample nor-

mally consists of three sheets, one taken from near the top of the flitch, one from about the middle and one from near the bottom. The flitch identification number is marked on these samples together with the total square footage in the flitch. These samples are sent to salesmen who sell the entire flitch based upon the samples shown. The importance of preserving sheet sequence of face stocks now becomes evident. The buyer in examining the sample sheets can determine the degree of uniformity of figure in the entire flitch, and whether it is suitable for his needs. A uniform figure is essential to the manufacturer who matches veneers to produce highly figured panels. A prospective buyer can also determine length, width and thickness of sheets, variation in color and smoothness of cut from properly selected samples of this sort. Practically all face veneers are sold in this manner.

In normal times some 80 or more kinds of face veneers were offered to the trade. Importation of exotic woods was greatly curtailed during the war, and many stocks have long since been exhausted. Several of the most popular species, however, are again beginning to appear on the market. Among the American hardwoods, black walnut (*Juglans nigra* L.) bole-wood, stumpwood, burls and crotches, quartered red and white oaks (*Quercus* spp.), sugar maple (*Acer saccharum* Marsh), quilted maple (*A. macrophyllum* Pursh) and figured red gum (*Liquidambar styraciflua* L.) have enjoyed extensive use. The more popular exotic woods were the American mahoganies (*Swietenia Mahagoni* (L.) Jacq. and *S. macrophylla* King), the African mahoganies (*Entandrophragma* spp. and *Khaya* spp.), Indian rosewood (*Dahlbergia latifolia* Roxb.), Brazilian rosewood (*Dalbergia nigra* Fr. Allem.), zebrawood (*Brachystegia* spp.), avodiré (*Turraeanthus africana* Pell.), bossé (*Guarea cedrata* Pell), Macassar ebony (*Diospyros* spp.), lacewood (*Cardwellia sublimis* F. Muell.), red lauan (*Shorea negrosensis* Fox.), orientalwood (*Endiandra Palmerstoni* C. T. White), prima vera (*Tabebuia Donnell-Smithii* Rose), tigerwood (*Lovoa Klaineana* Pierre), Ceylon satinwood (*Chlorophora swietenia*) and West Indies satinwood (*Zanthoxylum flavum* Vahl.). Prices per square foot ranged from two to thirty-five cents per square foot, depending on quality, figure, scarcity and demand.

Specially prepared, very thin face veneers reinforced with cloth or canvas backings and suitable for hanging on plaster, much in the manner of wall paper, are sold under the trade name of "Flexwood".

2. *Commercial veneer manufacturers.* Commercial veneers, or "utility" veneers, are those used for cross-bands, cores and backs of plywood panels, and for concealed parts of furniture, such as drawer bottoms, case and mirror backs, and dust sealers. These are rotary cut and are made from several species of domestic woods. Manufacturers of veneers of this sort are usually located with respect to adequate supplies of suitable timber. Beech, birch, maple and basswood veneers are produced in large quantities in Wisconsin, Michigan and New York. Red and sap gum, yellow poplar, cottonwood, tupelo, sycamore and oak veneers are made in many southeastern plants from the Ohio River region to the Atlantic and Gulf coastal plains.

Unlike the manufacturer of face veneers, commercial veneers are cut to order, species, thickness, sheet size and grade requirements being specified. A few, however, restrict their production to sheets of a standard size. Most commercial veneer is sold to furniture, piano or radio manufacturers who make their own plywood or to plywood plants that build stock panels or who manufacture

panels to customer specifications. In several instances a veneer plant is but a part of a large mill manufacturing plywood panels, in which case the entire output of veneer is consumed in the fabrication of panels within the facility.

FIG. 12 (*Upper*). Two-piece match, mottle brown stripe, of Honduras mahogany. FIG. 13 (*Lower*). A modern radio cabinet constructed with veneer. (*Photos courtesy Mahogany Association, Inc., Chicago.*)

3. *Container veneer manufacturers.* Facilities of this sort manufacture a wide variety of cheap veneers suitable for crates and packing cases, hampers, fruit and vegetable baskets, kits, meat, butter and picnic dishes, cheese boxes,

barrels, hoops and similar items. Such plants are usually established proximate to adequate supplies of cheap timber and suitable markets. When wire-stitched or stapled, and scored merchandise is made, a preference is usually shown for woods of lower density, such as cottonwood and sap gum.

Softwood veneer manufacturers are concentrated along the Pacific rim where several large and very modern plants are engaged in the production of rotary cut Douglas-fir, Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and ponderosa pine (*Pinus ponderosa* Doug. in Lawson) veneers. Substantial quantities of Port Orford cedar (*Chamaecyparis Lawsoniana* (A. Murr.) Parl.) sliced veneer are used in manufacturing storage battery separators. In the southeastern United States bald cypress (*Taxodium distichum* (L.) Rich.) and several of the southern yellow pines are used to a limited extent in the production of core and cross-band materials for use with hardwood face veneers.

More than 80% of all softwood veneers cut in the United States are made from Douglas-fir. The Douglas-fir industry has made tremendous strides during the past decade, and in the year preceding V-J Day had expanded its facilities to the point where it was capable of producing more than six billion square feet of veneer annually.

Douglas-fir veneer is almost entirely consumed in the fabrication of structural plywood panels and for interior paneling. Some container veneers are manufactured from Sitka spruce and ponderosa pine where they find a ready market in the citrus industries of California and the hard and soft fruit growers of the Pacific Northwest.

Plywood Manufacture

Of particular significance in the fabrication of a plywood panel is its balanced construction. A balanced panel is one that has an equal amount of wood in each grain direction and is symmetrical on both sides of its center line. Thus in 3-ply construction the thickness of the core is essentially equal to that of the combined thicknesses of the face and back sheets. In a 5-ply panel the combined thicknesses of the cross-band layers (Fig. 1) corresponds to the aggregate thickness of face, core and back plies. Panels composed of 7, 9 or more plies are similarly constructed. Construction of this sort provides for maximum strength and materially equalizes the strain in all directions. It also minimizes shrinking or swelling due to atmospheric changes and is thus considerably more stable than ordinary lumber. If properly constructed, warping is eliminated.

The manufacture of a plywood panel consists of (1) preparing face and back, cross-band and core sheets, (2) edge-jointing individual plies preparatory to forming large continuous sheets when required, (3) laying up and spreading the adhesive, (4) pressing the glued stock into a panel, and (5) drying and finishing the panel.

Veneers delivered to a plywood manufacturer are checked for moisture content, and, if necessary, are redried. If the sheets are not wide enough to make a panel of required dimensions, two or more sheets are spliced together to attain the necessary width. This is done by running the sheets through an edge joiner which makes a smooth straight edge. The sheets are then butted together along these dressed edges and fastened together with paper tape or a film of glue. This splicing operation is done mechanically with machines called tape splicers, or, if glue is used, tapeless splicers, and are standard equipment in nearly every plywood factory.

When figured sheets of face stock are built up in this manner, it is common practice to reverse (turn over) each

alternate sheet when an even number of them is used. In this way it is possible to form pleasing patterns of bilateral symmetry (Fig. 12). This practice is one form of matching veneers.

The next phase of panel manufacture is the gluing operation. In 3-ply panel lay-up, a dry back ply is placed on a caul.[6] If the liquid adhesive is used, the core sheet is run through a pair of rolls rotating in a bath of the adhesive, the glue spreader. These rolls are so adjusted that the thickness of spread may be regulated in accordance with the glue manufacturer's recommendations. The core in turn is placed upon the back ply, and a face sheet is then laid upon the core. This procedure is repeated until a stack of panels has been built up that will completely fill a press. The elapsed time between the initial spread of glue and the development of full pressure in the press is very important, particularly when synthetic resin adhesives are used, since a pre-cure without adequate pressure invariably results in no bond strength. Accordingly, this operation is carefully regulated in order to avoid such an eventuality.

Fabrication of 5, 7 or more ply panels is very similar. In such instances the cross-bands are usually run through the glue spreader. When double spreading is practiced, all plies are spread, the face and back sheets being run over a single glue-spreading roll.

Where cold pressing is practiced, that is, when glues are used that will cure at room temperature, wooden cauls are employed. Cold-pressing is usually time-consuming, however, since several hours or even days are required to effect a complete cure of the adhesive. Thus a plant using cold-pressing procedures must provide for ample press capacity. Cold pressing may be accomplished in screw presses, screw clamping devices, or in a variety of hydraulically operated machines.

Hot-pressing, on the other hand, involves the use of heat to effect the cure of an adhesive. When hot pressing is employed each lay-up is placed between a pair of metal cauls. Figure 11 illustrates a modern multi-platen press used in the manufacture of hot pressed plywood. The platens are hydraulically operated and internally heated. When the press is opened a lay-up between two cauls is laid on each platen. As soon as the press is charged it is closed and full pressure built up as rapidly as possible. Presses of this sort will bond wood satisfactorily in two to 30 minutes, depending upon the thickness of stock and distance of the glue line farthest removed from the heat source, nature of the adhesive and platen temperatures employed.

In recent years the use of radio frequency heat has also been used successfully in curing plywood bonds.

After their removal from the press, panels are often permitted to recondition (moisture stabilization) and are then cut to size and finished in accordance with customer specifications. If the faces are made up of spliced sheets, the tape which is always on the outside of the panel is sanded off.

Plywood Adhesives. Adhesives suitable for bonding of plywood panels must be of such a nature that they may be spread easily and uniformly. They must not impart objectionable stains to the veneers, nor should they lose any of their bonding strength upon aging. In some instances it is essential that they be highly water-resistant.

Six classes of adhesives are currently used in panel fabrication, *viz.*, hide and animal glues, starch glues, casein glues, blood albumin glues, vegetable protein glues and synthetic resin glues. Hide glues, once the most universally used,

[6] Cauls are sheets of aluminum, or plywood with oiled or waxed surfaces, used to equalize pressure and hold them flat during the pressing operation.

are now rapidly disappearing from plywood plants. Blood albumin glues have been very popular in European countries, but have had only limited use in the American industry. Starch glues first appeared on the market about 1912, while casein adhesives were an outgrowth of World War I. The vegetable protein glue, a soybean derivative, appeared on the market about 1923. The first of a series of synthetic resin adhesives made its appearance in 1935, and in the short space of a dozen years nearly the whole plywood industry has gone over to their use.

Synthetic resin adhesives are thermosetting plastics, which when cured, form hard, infusible films of great strength. At present there are two important classes of thermosetting resins available, *viz.,* the phenol-formaldehyde (including resorcinol) types, and the urea-formaldehyde (including melamine) types. Within these two general categories are many formulations, the choice of which is largely dependent upon the nature of the product being manufactured, durability of the bond, pressing equipment available and considerations of cost.

Phenol-formaldehyde resins are available in sheet form (Tego film), as a liquid, or as a dry powder that may be mixed with water, alcohol or acetone. Resins of this sort are used when hot-press plywood is made. Platen temperatures of 260° F. or more are usually required to effect total cure, although there are certain formulations available, called warm setting phenolics which may be cured at much lower temperatures. Resins of this sort form water proof, boil proof bonds, and plywood made with them is suitable for many external uses, such as hulls for small boats, aircraft and external paneling in house construction.

Resorcinol-formaldehyde resins are of the phenolic type but may be cured at room temperature. If temperatures are elevated to 150° to 200° F. cure may be effected in a matter of minutes.

Urea-formaldehyde resins are supplied in liquid or powder form. These resins will cure at room temperatures, but if heat is applied the reaction is greatly expedited. Urea resins are not as moisture-resistant as the phenolics, and if inadequate pressure is applied during the pressing interval, thick glue lines result. It is essential that the veneers bonded with urea resins be in intimate contact with one another, since thick glue lines eventually craze, and under such circumstances delamination is inevitable.

Melamine-formaldehyde resin adhesives are among the newest of the synthetic bonding agents. They possess many properties intermediate between the ureas and the phenolics.

Molded Plywood. Panels with single or double curvature, such as those used in aircraft skins, hulls of small boats, or in some of the most modern furniture designs, cannot be made with ordinary pressing equipment. Thus molding techniques, in which use is made of fluid pressures, have been devised.

In one molding process, veneers interleaved with film glue or coated with a liquid resin are laid-up upon a male mold of wood or metal and temporarily held in place with wire staples, tape, or by other suitable means. Such an assembly is then placed in a large flexible rubber bag from which the air is immediately expelled. As the vacuum is drawn the bag presses firmly against the veneers, causing them to conform to the contour of the die. The deflated bag and its contents are then placed in a large steel autoclave where steam or hot water is admitted under pressure. Adequate fluid pressure is brought to bear in this way and the heat cures the resin. At the completion of this cycle the molded item is removed and the operation repeated.

A somewhat similar process employs

the use of a female mold. In this instance veneers are laid-up along its inner face and covered with a rubber blanket attached to the die. Air is usually expelled beneath this covering so that the veneers are pressed firmly into place. This assembly is then similarly handled in the manner described above. There are a few variations of these two methods for molding panels of unusual shape and contour, all of which utilize a fluid pressure system to assure that adequate and uniform pressure is applied to the panel during the bonding cycle.

Densified Wood. Synthetic resin adhesives have made possible the development of densified wood, or "compreg". In practice, thin sheets of veneer are immersed in a bath of phenol-formaldehyde or other resin and subjected to vacuum-pressure treatment which alternately draws and forces resin into the interstices of the wood. When the veneers have picked up from 20% to 35% or more of resin, based upon the original weight of the wood, they are laid up in parallel laminates, or cross-banded as in normal plywood, and cured in a hot press. Full pressure of approximately 1,500 per square inch is developed before the assembly is heated. The temperature is then raised to produce approximately 300° F. of heat in the innermost glue line. Ordinarily presses are maintained at full pressure after completion of the bonding cycle until the center of the panel cools to 120° F. after heating is discontinued.

Compreg made of birch veneer has a specific gravity of from 1.30 to 1.36. It has excellent dimensional stability and mechanical properties except under impact loadings. During the War compreg was used for airplane propellers, parachute flare bases and reinforcing plates. It should be suitable for casters, pulleys, shuttles, bobbins and a host of other items. It has already been found suitable for picker sticks in the southern cotton mills.

Properties and Uses of Plywood. Pound for pound, plywood is stronger than steel. Because of its cross laminate feature, nails, screws and other wood fasteners may be driven close to the edge of a panel without fear of splitting. It has much greater stability than ordinary boards and exhibits little or no tendency to twist or buckle with fluctuations in moisture content. Plywood panels are not limited to narrow widths such as those of boards, but may be produced in wide faces wholly free from defect. Plywood fabrication permits perfect matching, the only method by which beautiful symmetrical grain-patterns may be achieved (Fig. 13).

In the modern post-war home may be found plywood walls, plywood flooring, plywood doors, plywood shelving, partitions and cabinets. Even the outside walls may be fabricated of weatherproof plywood. In our business offices, our public buildings and our shops and stores may be seen an ever changing array of plywood applications—desk tops, tables and chairs, counter tops, wall panels in elevator cabs, store fronts, show cases, window displays, filing cabinets, bulletin boards—all made of plywood.

Plywood is also an important item in the various fields of transportation and is used in enormous quantities in the fabrication of air- and water craft, railway cars, and in trailer and station wagon bodies.

Plywood is now a fully recognized engineering material just as are metal alloys and ceramic materials. Years of painstaking research by wood technologists, engineers and chemists, all working together, have made modern plywood what it is today—a truly superior wood of many and diverse uses.

Henbane—*Healing Herb of Hercules and of Apollo*

This poisonous drug, formerly available only from Europe, India and the Sudan but now produced also in the United States to the extent of 80,000 pounds annually, has been used therapeutically since ancient times and today has common use in modern medicine.

GEORGE M. HOCKING[1]

Introduction

HENBANE is an official drug in the United States Pharmacopoeia where the name "Hyoscyamus" is used for both the English and Latin titles. It is described as consisting of the dried leaves with or without the flowering and/or fruiting tops of *Hyoscyamus niger* L. Likewise official in the U. S. Pharmacopoeia are the herbs prepared from the two other most important medicinal members of the family Solanaceae, namely, belladonna (*Atropa Belladonna* L.) and stramonium (*Datura Stramonium* L.). Of parallel value, therapeutically, they likewise have all been official in the U. S. Pharmacopoeia since this chief official compendium first appeared in its 1820 edition. The importance of Henbane is further witnessed by its being official in nearly if not all present-day national pharmacopoeias, approximately 20 in number.

Besides the leaves, optionally with tops, other parts of the plant have been used, either officially or unofficially, *viz.*, herb, seeds, fruit, root, stalk (Dioscorides), *etc.*, not to mention the expressed juice and the smoke.

Geographical Origin and Distribution

The species *Hyoscyamus niger* is believed to have been originally a denizen of Eurasia, and is now distributed throughout Europe from Portugal and Greece, on the south, to Norway and Finland, on the north. It is found also in the Caucasus, Iran, throughout Asia Minor, in northern India and even in Siberia. The plant has been naturalized in North America, at least since about 1670, and now grows wild in the eastern, northern and western United States and in parts of Canada. It occurs chiefly in waste places, such as near buildings, on roadsides, in graveyards, old gardens, and in areas covered with rubbish from ruined buildings. In habitat, therefore, it considerably resembles its relative, stramonium, except for its more northerly distribution. The plant is now cultivated for medicinal use in a number of countries, including our own.

Common Names

As one might reasonably expect from its importance, the species under discussion has acquired many common or vernacular names. The most important names applied to the plant and the derived drug are in English: Henbane, so-called, maybe, because the seeds are said to kill fowl; Henbain; Hyoscyamus Leaves; Hyoscyamous; Henbane Leaves; Common Henbane; Black Henbane; Stinking Nightshade; Foetid, or Fetid, Nightshade; Insane Root; Poison Tobacco; Soldier's Herb; Soldier's Tree; Hogbean, because the plant is said to be eaten by hogs; Hog's Bean; Hogbane (?); Hen-bell. Older English words almost never heard now include belene;

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chenil(l)e, apparently stolen from the French; brosewort (?); hanebane; hainbane; henkam; hennebane; hennebone; hennibone and Stinking Roger.

In Latin the species has been variously known as Hyoscyami Folium, a title used by the International Pharmacopeia; Hyosciamus; Herba Apollinaris or Apollo's Herb[2]; Symphoniaca Herba, on account of the resemblance of the flowering and fruiting axis to the musical instrument of that era known as the symphonia; and Jusquiamus.

In France *H. niger* has been called la Jusquiame from the Latin "Jusquiamus"; Jusquiame Noire; Potelée; Herbe-des-chevaux; Hanebane; Hanibane; Hannebanne (Gaston Bonnier), and so on. In German the drug is (Schwarzes) Bilsenkraut; Bilsen; Dullkraut; *etc.* In Dutch the species is known as Bilsenkruid, *etc.;* in Norwegian, Bulmeurt; in Swedish, Bolmört. The common Spanish name is Beleño (Hojas); the Portuguese, Meimendro (Folhas); the Italian, Giusquiamo (Foglias).

Description of Plant

Hyoscyamus niger occurs in two distinct forms. One of them is the annual plant, of interest as having been specifically excluded from some pharmacopoeias (*e.g.*, U.S.P. 1880, 1890, and the eighth revision). The plant seldom grows higher than two feet, is slender in habit and little if at all branched. Its various parts develop on a smaller scale than in the biennial form. The leaves are less distinctly toothed and the corollas show little or no purplish veining. This is the form of the plant which was cultivated by the "herbalists" of a bygone generation.

The biennial form appears to be much the commoner. For instance, Stewart found that when seed of wild-growing Montana plants was sown, the biennial forms were produced.[3] During the first year of growth the plant develops a large whitish, fleshy, tapering, branched root, somewhat resembling that of a parsnip or small horse-radish, crowned by a radical rosette of large leaves, a foot or more long, with very long petioles and coarsely toothed, lobed or deeply cut blades. No aerial stem is produced. During the second year the plant throws up an erect, thick, coarse and widely branched stem, two and a half to four or even five feet tall, which bears flowers in long, secund, leafy, spike-like groupings. The flowers in this form have prominent purple vein markings on the corolla. Fruits are formed within the permanent calyx, and as these mature, the entire plant dies. At this stage the root becomes spongy and then hollow, and the radical leaves disappear, while those on the stem are found to be quite broad with relatively short petioles or even sessile near the top of the stem.

Wild growing plants near Bearmouth, Montana, were found by Stewart to have, instead of one flower stalk, as customary, several stalks (up to twelve) growing from a single root-crown. It was suggested that this was due to cropping of the first year's growth by sheep. The plants ranged from two to five feet in height, the taller growing in a shady ravine, the smaller in the sunlight on a hill-top. Undoubtedly the rich fertilized soil of the sheep corral, in which the plants grew, accounted in part for the luxuriant growth. No infestation or plant disease was noted, although such have been reported for plants growing farther east in Montana. Catnip, mullen and horehound were growing alongside. The plant thrives well in Montana to over 7,000 feet elevation, and in India it has been reported from altitudes of 8,000 to 11,000 feet.

[2] Apollo of the Greeks = Hercules of the Romans.

[3] These and other data in this article relating to Montana Henbane, unless otherwise stated, were gleaned from the unpublished M.S. Thesis of George W. Stewart of the State University of Montana, 1934, kindly loaned to the author.

Cultivation

Some people who have cultivated a variety of medicinal plants state that henbane is one of the most difficult of its family to rear successfully, *i.e.*, to produce a drug meeting official requirements.

Experiments in cultivation have been carried out in the Drug Garden of the School of Pharmacy at the State University of Montana (Missoula). The seed used was collected from a plot of wild-growing plants near Bearmouth, about 40 miles from Missoula. Seed was gathered the last of August and sown on April 15 of the following year (*ca.* 1933). Before planting, it was treated with 5% sulfuric acid for 20 minutes, then washed with water and dusted with lime to neutralize and provide calcium for the seedlings. Small shoots developed in about three weeks. The plants were thinned out several times during the season. Growth continued until the summer, when an arrest of growth occurred with the plants one-half to one foot high. The following spring the plants sent up flowering stalks which bore blossoms in July. These biennial plants appeared free from disease or infestation, although untreated by spraying, *etc.*

The transplanting of henbane seedlings from a greenhouse or cold-frame to the outdoor area has not been very successful, for most plants do not survive the shock of moving, and those that do are stunted in growth. This is said to be caused by injury to the tap root. Better results are achieved if plants are allowed to attain fair size before being moved.

Because of this obstacle to large-scale propagation, the Wisconsin Pharmaceutical Experiment Station at Madison years ago undertook experiments to determine whether the seed might not be sown directly in the fields, as is done with stramonium. Biennial seed was accordingly sown in early December, 1916, and began to come up about May 10, 1917, while some of the same seed sown on April 21 came up on May 16. Besides taking only one week more to emerge from the soil, the spring-sown seed gave a more uniform stand.

In growing henbane it is best to select a level area, as free as possible from weeds. A well drained fertile sandy loam or silt loam is considered best. One pound of seed is enough per acre and should be sown in rows two feet apart. If kept dry, henbane seed remains viable for several years, a fact which accounts for certain reported vagaries of growth. It is best to test germination of the seed before sowing. The best seed is that which has been specially collected for planting purposes. Pre-treatment of seed with concentrated mineral acid was reported to result in germination in about 20 days rather than the usual 30.

Sowing may be done by mixing the seed with sand and dropping it into shallow holes. Better still, a small seeder will give more uniformity. The seeding should be at such a concentration that one viable seed is laid every four inches along the row, and the seeds must not be covered by more than about one-quarter inch of soil.

Cultivation may be carried on before the young plants appear, if the rows can be distinguished or have been properly marked. Later on, regular weeding should be practised, and if necessary the plants ought to be thinned out so as to leave them about four inches apart.

Harvesting of leaves and flowering tops is carried out when the plants are in full bloom (June to August) and before the first frost. Drying is best performed in a drying house, where the herbage may be spread in thin layers on floor, trays, *etc.* Drying is hastened and color and quality improved by using a small amount of heat and air currents.

A yield of 600 pounds of Henbane per

acre may normally be expected. Almost twice as large a crop per acre may be obtained from the first- as from the second-year plants.

Infestations and Diseases

From the literature it appears that the Colorado potato beetle is henbane's worst enemy; it has been said to prefer henbane to all other plants. If the plants are not to be entirely destroyed by this pest, they must be sprayed with an insecticide. In the past, lead arsenate has been mostly used. Paris Green was found destructive to the plant, and sulfur soon loses its effect on the insects which prey on it. Two sprayings of 1 to 1,000 suspension of lead arsenate during the life-time of the plant are said to be adequate. Among the fungi reported as attacking ***Hyoscyamus*** are *Peronospora* (Phycomycetes) and the mildew ***Erysiphe*** (Ascomycetes).

Commerce

Before World War II most Henbane drug imported into the United States came from Europe, chiefly Hungary, Belgium, France, the Soviet Union, Germany and Italy. During more recent times exports have come chiefly from India, the Sudan, the United Kingdom, the Soviet Union and elsewhere, but the largest bulk has been domestically produced in the continental United States. At present the U. S. exports only a few thousand pounds of the approximately 80,000 produced here annually.

Montana is or recently has been the chief producing area for domestic Henbane, although the plant grows wild commonly in sections of the other northwestern States, *i.e.*, Idaho, Washington and Oregon. The plant is said to have first been observed growing in Montana at Big Timber, in the year 1883. The plant grew from a pile of dirt thrown from the basement of an hotel under construction. It is thought that a workman engaged in the labor dropped smoking tobacco admixed with the seed, since it is known that henbane seed has sometimes been mixed with tobacco to bestow a narcotic effect.

The species was subsequently collected in 1900 at Billings, Big Timber, Bozeman and elsewhere in Montana, and was spread to other parts of the State by admixture with hay, it is thought. Thus, the patch at Bearmouth is believed to have come from seed of plants mixed in hay for feeding horses used by convict labor when the Missoula-Deer Lodge road was built.

Henbane has sometime been marketed in grades representing stages of growth: (*a*) "Annual" or "seedling"; (*b*) "First Biennial", for leaves or herb of the biennial plant in its first year of growth; (*c*) "Second Biennial", for leaves of second year. The last item is scarce and high priced. In opposition to earlier opinion, first-year leaves have an alkaloid content similar to that of second-year leaves and are now considered equally as useful medicinally. However, they contain more acid-insoluble ash (sand, dust, *etc.*), no doubt because they are entirely basal leaves and not partly basal, partly stalk-leaves.

Description of Drug

The crude drug consists of much wrinkled, matted and broken leaves mingled with many stems and flowering and fruiting tops. The leaves are ovate to ovate-lanceolate, up to 26 cm. long and 10 cm. wide, not evenly divided by the mid-rib, the lower leaves petiolate, with petioles up to one-third the length of the blade, and the upper leaves stalk-less. The tips of the leaves are acute, the margins irregularly dentate (toothed) or pinnatifid (deeply lobed), with acute deltoid lobes. The upper surface of the leaf is darker than the lower. The leaf color is a shade picturesquely described by Parkinson

(1640) as a "darke or evill grayish greene colour". The same Apothecary and Botanist to the King gave the odor of the entire plant as a "heavie evill soporiferous smell somewhat offensive". Others have called it "dank", "benumbing", "narcotic", "noisome", "horrid", "heady", peculiar, strong, unpleasant, rank, distinctive, heavy, fetid, and so on. The aroma of Henbane has been compared to that of fresh tobacco, black currant leaves, and musk. The taste of the crude drug is bitter and acrid.

Henbane flowers are nearly sessile, with an unequally five-toothed, urn-shaped, hairy calyx, and a yellowish, campanulate, slightly zygomorphic corolla, with purplish veins. The corolla ends in five unequal obtuse lobes, and five stamens are inserted in its tube.

The fruit consists of a two-chambered pyxis (urn-shaped type of capsule which dehisces or opens by separation of a lid-like top) enclosed in the persistent calyx. When found, the seeds are black (hence the specific name of the plant) to dark gray, round-oval, numerous, tiny, unequal and hard.

The stems are two to seven mm. in diameter, somewhat compressed or cylindrical, longitudinally wrinkled and hairy.

The powdered drug is dull grayish-green to dark green. When examined under the microscope, it reveals calcium oxalate crystals in the form of monoclinic prisms, as twin crystals and as rosette aggregates (the latter not common). Non-glandular hairs are found, ranging from one to ten cells in length—these are often broken up in the powdered drug. Glandular hairs with a one- to four-celled stalk and a unicellular or multicellular secreting head also occur. Newcomb observed that very large branching non-glandular hairs, which had not previously been described for this plant, presumably because they are of relatively soft structure, are found on green plants and apparently soon disappear when the plant is dried and handled.

Also observable microscopically are epidermis fragments with broad elliptical stomates having three or four neighboring cells, one of which is smaller than the others; fragments of tracheae with pores, reticulations and spiral markings; bast fibers; and pollen grains which are nearly smooth and bear three furrows.

Chemical Constituents

Henbane contains several important constituents, the two most important being the alkaloids hyoscyamine (crystalline) and scopolamine or hyoscine (amorphous). Minor other alkaloids, *e.g.*, scopoline and tropine, are present in traces.

Scopolamine was first isolated from the herb in 1833, and was obtained first from the seeds in 1871. It is a syrupy compound in the free state, but a crystalline solid in the form of the common salts. Scopolamine hydrobromide is official in the U. S. Pharmacopoeia and is used considerably in medicine, both by mouth and hypodermically. Henbane is not, however, the chief source, since this alkaloid is obtained mostly from *Datura* species, a related group in the Solanaceae.

The other alkaloid, hyoscyamine, is not now commonly used in medicine and is no longer official in the national compendia which serve as standards for American drug products.

Other components of Henbane which have been isolated are hyoscipicrin (a glycoside), choline, mucilage, albumen, chlorophyll and potassium nitrate. The last compound (salt peter) is presumed to cause the characteristic sparkling effect seen when the dried leaf is ignited. The seed contains much fatty oil (about 25%) and also a little volatile oil.

Analyses of Domestic Drug

According to U. S. Pharmacopoeia XIIII, the drug Henbane must contain

not less than 0.040% of the alkaloids characteristic of the plant. This is a lower requirement than that in earlier pharmacopoeias (*e.g.*, U.S.P. IX, X, where not less than 0.065% alkaloids was required, or U.S.P. VIII set 0.080% as a minimum).

Analyses of Montana Henbane, the chief domestic type, show that most lots are comfortably above the minimum required strength, as at present defined. Thus, one crude-drug concern[4] has furnished the following values for commercial batches of the Montana product:

Number of lots		*Test (% total alkaloids)*
1		0.042
4		0.054
7		0.060
3		0.061
5		0.065
4		0.073
1		0.078
1		0.090
Total 26	Average for all lots	0.0633

From this it appears that 15 or more than half of the lots were below the former official strength, while the average assay of all lots was less than the former required figure. On the other hand, all lots meet the present minimum assay requirement, and one of them is more than twice as high as the needed assay.

Stewart found that the U.S.P. X assay method was unsatisfactory in assaying the Montana drug with which he worked[5], due to the formation of very stubborn emulsions in "shaking out" the alkaloids. By this method the Montana drug assayed only 0.005% (average), while commercial imported Henbane ran 0.0867% or about 17 times as high. To help remedy this, the drugs were first defatted with petroleum ether. Assays then ran higher (0.030% average for domestic; 0.078% in commercial drug).

In order to partially simulate conditions undergone by the commercial drug, the Montana material was heated at 95° for two weeks to drive off volatile matter. After this treatment the drug was of much the same color as imported material and had lost much of its offensive odor. In conducting assays with this, no difficulty was had with intractable emulsions, as before. Material so treated averaged 0.044% alkaloids (imported drug 0.071%).

Finally Stewart tried the method of C. M. Caines (1929), which seemed an improvement over other methods, and this gave results indicating a Montana product almost meeting the then current official standards, since the average of determinations was 0.057% (imported drug 0.081%).

Stewart also made other chemical studies on the Montana Henbane (same material as that used for alkaloidal studies). He obtained the following values:

Loss on air drying (25° C.)	88.18%
Total volatile matter[6]	10.89% (aver.)
Total ash	19.25% (aver.)
Acid-insoluble ash (not more than 12% allowed, U.S.P. X–XIII)	2.73% (aver.)

Successive extractions by Soxhlet method:

Petroleum ether	5.67%	(average	imported,	3.35%)
Ethyl ether	5.10%	"	"	2.49%)
Alcohol	23.91%	"	"	16.87%)
Dist. water	20.68%	"	"	20.99%)

Other findings were:

Crude fiber	6.11%	"
Total nitrogen (in leaves)	4.24%	(average)

[4] S. B. Penick & Company, New York; data furnished through the courtesy of Dr. Thomas Lewis, Vice President and Technical Director.

[5] Material was collected from wild-growing plants close to the Butte-Missoula highway near Bearmouth. The leaves and flowering tops were collected June 28, 1933, dried and ground to a #40 powder.

The seeds of Montana henbane were also studied by Stewart. He reported in his Thesis the following values from chemical tests carried out on the seeds ground to a fine meal (all figures are averages):

Volatile matter (100° C.)[6]	10.39%	
Total ash	2.87%	
Acid-insoluble ash	0.41%	
Successive extractions by Soxhlet method:		
Petroleum ether	32.63%	The bulk of this extractive (non-volatile) is of course the fatty oil.
Volatile portion	1.95% (of crude)	
Ethyl ether	31.14%	
Volatile portion	3.42% (of crude)	
Alcohol	24.61%	
Distilled water	6.60%	
Crude fiber	25.33%	
Total alkaloids	0.093%	(after defatting seeds)
" "	0.130%	(by Caines' method)

The fatty oil was extracted from the seeds with petroleum ether, then the solvent evaporated and the oil filtered through cotton. The fixed oil constituted about 25% of the seeds (W/W). It was amber-colored with a bland innocuous taste and very little odor. The following constants were reported by Stewart:

			Values of Bureš and Kracík (cold extraction)
Spec. Gravity (25° C.)	0.9183		0.9120–4 (d15°)
Refract. Index (25° C.)	1.4739		
Saponification No.	191.72	(average)	187.8
Iodine Absorption No.	82.07	(average)	135.7

The figures for the Montana seed oil and that of Bureš and Kracík for plants grown in Czechoslovakia are far from concordant, but may be partly explained by the differing habitats and latitudes.

[6] Determined by heating in oven at 100° C. until of constant weight.

Derivatives and Preparations

It is typical of the human being to attempt to improve on nature, and in the field of medicine we find no exception. Instead of administering the whole leaf of henbane, or its powder, it has been customary to give either the so-called galenical preparations, such as tinctures, extracts, *etc.*, or the alkaloids. From an historical standpoint the preparations are of much greater importance, and the elegance and imaginative titles which have distinguished many of them are quite interesting. A mere listing of the titles, in some cases translated into English, is very revealing of the human ingenuity displayed in the administration of this one drug:

Modern or Current:
- Tinctures
- Fluidextracts
- Extracts (both semi-solid and powdered)
- Fomentations
- Compound Oils (Infused Oils, *etc.*)
- Abstracts
- *etc.*

Formerly popular (as described in the Universal Pharmacopoeia, published at Weimar in 1845):
- Anticephalagic Paste (for frontal headache)
- Anodyne Cataplasm
- Electuary for Hemoptysis (spitting of blood)
- Conserve (made with white sugar !!)
- Oil of the Seed
- "Paregoric Oil"
- Hemorrhoidal Ointment
- Juice
- Seed Extract
- Fecula (a starchy preparation)
- Syrup
- Narcotic Boli (large pills)
- Pills
- Pills of Extract
- Narcotic (or Sedative) Pills
- Antichoreic Pills (for St. Vitus' Dance)
- Anti-hysteric Pills
- Anodyne Pills
- Anodyne and Resolvent Liniment
- Pomade
- Antispasmodic Elixir
- Collyrium (Eye Wash)
- Sedative Narcotic Haustus (Draught)
- Breast Draught
- Expectorant Draught
- Enema
- Infusion
- Sedative Emulsion
- Anti-odontalgic Collutorium (Mouth wash for toothache)
- Narcotic Cataplasm
- Alcoholic Extract
- Essence

Tincture of Seeds	Anodyne Ointment
Ethereal Tincture	Tranquil Balsam
Green Oil	Ear Oil
Ointment	Sedative Liniment
Plaster	Compound Poplar Ointment
Unguentum ad Ambusta seu Combustiones (Ointment for burns or burnings)	Hemorrhoidal Lotion
	Etc.

Uses in Medicine

The physiological action of Henbane is similar to that of Belladonna, Stramonium, Scopola and similar drugs of the Solanaceae. While less powerful than they, Henbane is relatively more sedative and hypnotic and causes little or no constipation and other unwanted by-effects.

Ancient Uses. Henbane has been employed as a medicine from very early times. Baron Hammer-Purgstall actually believed "bendj" (Arabic for Henbane) was the Nepenthe of Homer. White Henbane was one of the "simples" used by Hippocrates (5th Cent., B.C.). This plant is quite similar to our Henbane in medicinal effects.

Dioscorides (A.D. *ca.* 60) called the plant "hyoscyamos" (literally "hog's bean"), but he also mentions "dioskyamos" (bean of the gods) as an outmoded name, possibly so-called from the usage of the drug in the temple "mysteries" or religious rites. In his works Dioscorides described three species—black, white and yellow. Of these he particularly commended the "white" as being the least dangerous. (As a matter of fact, it closely parallels black Henbane medicinally, although rather weaker in action). Dioscorides recommended the root with vinegar as a mouth-wash for toothache, and 17 or 18 centuries later we find still prescribed an Antiodontalgic Mouthwash made from a mixture of henbane and plantain leaves with violet and red rose flowers, poppy heads and sage leaves in water, properly processed. Not as useful perhaps as the modern novocain or even clove oil, yet this preparation doubtless eased the pain of many a case of odontalgia. Another application of Henbane for the same purpose during the past few centuries has been that of burning the seeds and funneling the fumes into dental cavities in an effort to expel the "tiny worms" believed to cause the distress resulting from caries.

Pliny (fl. 60 A.D.) recognized the psychogenic qualities of the drug when he wrote:

"Henbane is of the nature of wine, and therefore offensive to the understanding, and troubles the head. . . . [It ought] to be used with great heed and discretion. For this is certainly known, that, if one take of it in drink more than four leaves, it will put him beside himself".[7]

An early contraceptive was made by mashing the seeds into paste with mare's milk and tying the paste in a piece of wild bull's skin.

In the Middle Ages Henbane was used legally as an anesthetic (with opium, mandrake, hemlock juice, aconite, datura, *etc.*) in the form of a "soporific sponge" and of the "pomander" (sleeping apple), acting through inhalation; it was also employed illegally as a sleeping potion, much as "knock-out drops" are used in our time. Gui de Chauliac of the 14th Century thus described the use of a narcotic inhalation:

I'll imitate the pities of old surgeons
To this last limb, who, ere they show their cut,
Cast one asleep, then cut the diseased part.

The medicinal popularity of Henbane dropped after the Middle Ages along with that of Belladonna, until by the 1700's it fell into disuse and was omitted from such compendia as the London Pharmacopoeias of 1746 and 1788, being returned only in the edition of 1809. Henbane was reintroduced into occidental medicine chiefly as the result of original labors by Professor Baron

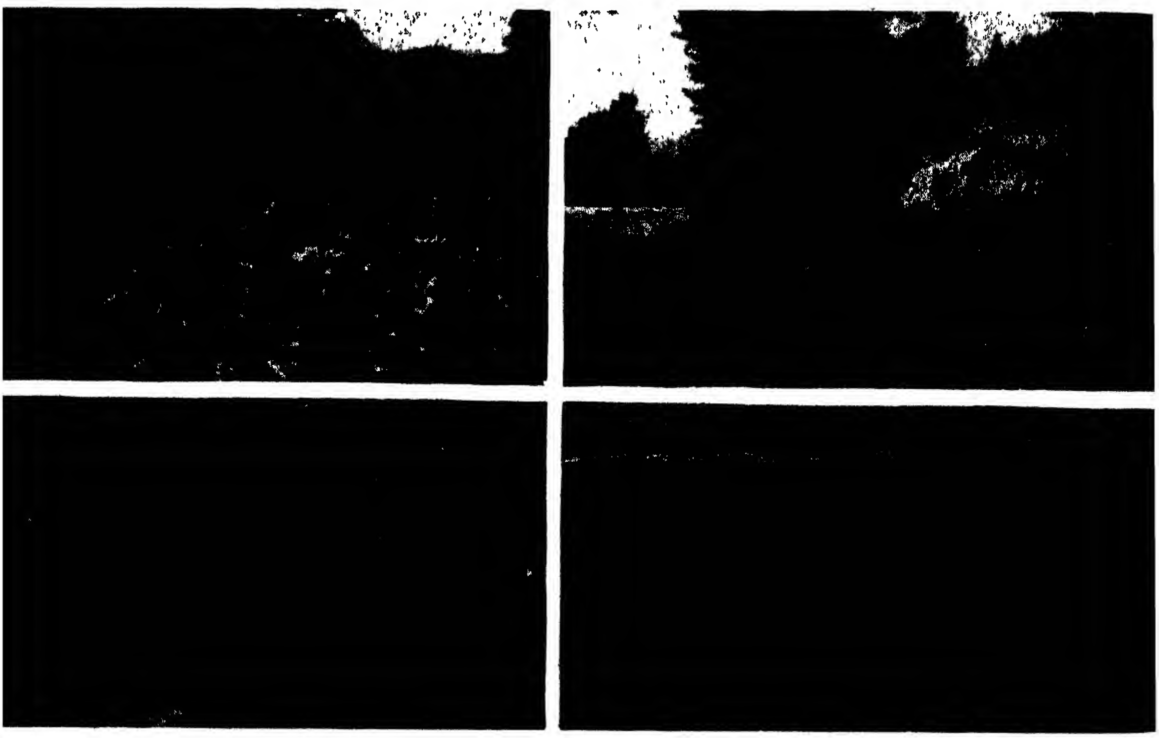
[7] Holland's translation (1601), revised.

Storck of Wien, who in 1762 carried out an investigation of the remedial value of Henbane, Stramonium and Aconite.

The Arabians, too, were familiar with the medicinal value of Henbane, as may be gathered in part from the following extract from that great anonymous classic, "The Thousand and One Nights":

"Presently he filled a cresset[8] with firewood on which he strewed powdered Henbane, and lighting it, went round about the tent with it till the smoke entered the nostrils of the guards, and they all fell asleep, drowned by the drug".

Modern Uses. During the past century and a half Henbane has found many uses in western medicine, uses depending on its value as an anodyne (pain reliever), hypnotic (sleep promoter), narcotic, mydriatic (eye pupil enlarger), mild laxative, carminative (digestion aider), sedative (nerve quietener) and antispasmodic (spasm antidote). Thus, Henbane has been used as a sedative in acute and chronic mania, epilepsy, hysteria, "hypochondriac monomania," delusional insanity ("madness")[9], melancholia, nervous or irritable cough, tremor in paralysis, febris nervosa (where fever arises from purely nervous disturbances), insomnia with hallucinations, delirium tremens, priapism, *etc.* It is used for its anodyne properties in angina pectoris, arthritis, rheumatism, locomotor ataxia, colica pictonum (colic of lead poisoning, lead colic, or painter's colic), other colics, podagra (or gout), neuralgia, gastralgia (stomach ache), cephalgia (headache), teething of babies[10], *etc.* As an anti-



FIGS. 1–4. Henbane growing wild in a sheep corral and elsewhere near Bearmouth, Montana. (*Courtesy G. W. Stewart.*)

[8] A holder for torches and other burning objects.

[9] Strange to say, Henbane is also said to cause insanity.

[10] Formerly, pieces of the root were strung around the neck of the baby to form the so-called "anodyne necklace".

spasmodic it was and sometimes still is used in asthma, chorea (St. Vitus' dance), tetanus, constipation, whooping cough, phthisical coughs, croup, *etc.*

Hyoscyamus is sometimes used locally for applying to painful swellings, irritable ulcers, tumors, severe chordee, orchitis, *etc.*

A most important modern usage of Henbane and other solanaceous drugs is as a corrective for griping medicines, such as strong purgatives. It serves as an antidote in poisoning by mercury and other agents, and is occasionally used in treating the morphine habit.

Henbane is sometimes used also as an hypnotic, *etc.*, where opium derivatives cannot or are best not used, as for children.

Among the so-called "mydriatic" or "solanaceous" alkaloidal drugs, Henbane is ranked in importance next after Belladonna. The average dose is 0.2 Gram.

Non-medicinal uses include its employment for ages by professional poisoners. And finally, the leaves of the plant are said to repel mice.

Poisoning

The toxic properties of white Henbane have been recognized since long before the time of Christ. Poisoning comes about generally from the ingestion of doses larger than medicinal, and as a rule are seen where an overdose of medicine is taken, or where a part of the plant is accidentally consumed, as by children. Most recent poisonings described have been from one of the alkaloids.

Poisoning begins with the development of mouth dryness, burning throat, pupil dilatation, visual disturbances, giddiness, nausea and hallucinations. If remedial measures are not taken and the dose is sufficiently large, more serious symptoms ensue, such as difficult respiration, delirium, feeble quick pulse, coma, convulsions and finally death by paralysis of respiration. Fairly characteristic is the reddening of the skin of face and neck, somewhat reminiscent of that in scarlet fever, but in later stages of poisoning the skin becomes cold and clammy, although the rash may persist even after death. Most characteristic of all, at least for the solanaceous group, is the persisting enlargement of the pupil of the eye. This mydriatic effect commonly continues for several hours after death.

Treatment is best conducted by washing out the stomach with a stomach-pump, using tannic acid in the wash water. As antidotes, morphine or caffeine may be used with care.

Adulteration

Henbane is sometimes adulterated, although less often than formerly. *Hyoscyamus muticus* L. (Egyptian or Cyprus Henbane) leaves and tops have sometimes been seen admixed with the true Henbane. This is a particularly dangerous adulterant, because this plant is very much richer in alkaloid than our Henbane. Also, other unofficial Henbanes have been used at times to adulterate or sophisticate true Henbane. Also so used have been Stramonium, Belladonna, Mullen and Digitalis. Adulteration is best detected by means of the microscope, since when dried and crumpled, these various leaves have considerable similarity to the unaided eye. Thus, microscopically, Henbane is very readily distinguished from both Belladonna and Stramonium by its much greater coverage of the leaf by trichomes.

Other Hyoscyamus Species

Approximately 20 species of *Hyoscyamus* are recognized. One species, *Hyoscyamus albus*, has already received passing notice. It was used by the ancients for catarrh, cough, *etc.*, and the

natives of southern Europe, where it grows, still sometimes use the plant in much the same manner as we do our medicinal Henbane. They also grow it as an ornamental in flower gardens, and additionally *H. aureus* L., which also is occasionally used as a drug. The root and herb of *H. physaloides* L. was once used in Siberia in place of opium as a medium of exchange. *H. muticus*, already mentioned as an occasional adulterant of Henbane, is imported into this country in considerable quantities for use in alkaloid manufacture, as is well known. The alkaloid content is roughly 25 times as great as that of "Henbane Niger", as true Henbane is sometimes referred to in commerce.

Utilization Abstracts

Bamboo Pulp. "The future for white paper made of bamboo is bright. Runs made a few months ago were so successful that one concern is contemplating cultivation of bamboo in Texas for commercial use. Only a few of the 123 varieties now being grown in a United States Experimental Station near Savannah, Georgia, have been tested, but further research is now being carried on". (*Pulp and Paper Bulletin, as reported in Chemurgic Digest 5(13): 235. 1946*).

Cork Oak in Maryland. Through the cooperation of the Crown Cork and Seal Company of Baltimore and the Maryland Department of State Forests and Parks, experimental plantings of cork oak, *Quercus Suber,* have been made in Maryland. It has been found that the southern counties and the Eastern Shore of the State are suitable for growth of this tree which is native to the western shores of the Mediterranean. It is hoped that this may indicate possible future commercial production of cork in the State, not only as a forest crop but also on farms where the acorns would be of value as hog food.

"For normal peacetime manufacturing requirements in the United States about 160,000 tons of cork are imported annually. Sixty percent of the cork brought to this country is used in the manufacture of cardboard insulation. Other uses of cork include: floats for gauges and fishing nets, life jackets, shoe inner soles, printing press blankets, closure liners, ring buoys, gaskets of many kinds for automobiles, tractors, trucks, household appliances and industrial equipment, linoleum, cork tile, sporting goods and novelties". (*G. B. Cooke, Chemurgic Digest, 5(10): 187. 1946*).

Charcoal. Charcoal is produced either as the residue from wood distillation operations in large retorts, or by incompletely burning wood under an earth blanket to carbon without any consideration being given to the volatile products driven off. In the northeastern States there are four main uses of charcoal:

First, in shade-tobacco curing sheds. About 7,500 tons are annually used for this purpose in the Connecticut Valley, some of it in the form of briquets obtained, when available, from the Ford Motor Company in Michigan. These briquets are molded from powdered charcoal with starch or other material as a binder.

Second, as fuel for home cooking by the foreign-born population.

Third, in industrial operations, chiefly brass and other metal industries, where charcoal possesses qualities particularly valuable to the processes.

Fourth, as a purifying agent. Pulverized charcoal, treated to drive off the hydrocarbons, is converted into "activated charcoal" which possesses absorptive qualities as a refining and purifying agent. Water companies use it to remove tastes and odors from drinking water. (*E. L. Heermance, Chemurgic Digest 5(10): 188. 1946*).

veloped in Japan, and the use of agar grew rapidly, since it could be kept indefinitely in pure, dry form and could be transported cheaply to inland localities. Foreign demand for agar began to develop during the nineteenth century, and the Japanese began to export in small quantities. It was at the beginning of the twentieth century that export business became an important part of Japan's agar industry.

manufacturing process, including a "dewaterer" and dehydrating tower, patented in 1929. Other factories have been established in California in recent years.

Although California factories produced only about ten percent of the 600,000 pounds of agar used in the United States in 1941, the outbreak of war found these producers ready to expand to such an extent that they were able to meet our domestic wartime requirements and to provide small quantities for export to allied nations.

FIG. 1. *Gracilaria confervoides,* the sterile, free-floating phase. (*Courtesy Duke University Press.*)

Development of the Industry in the United States

Chokichi Matsuoka, familiar with the agar industry of the Orient, observed that an abundance of *Gelidium cartilagineum* grew along the coast of California. He organized a company in 1919 that first began to produce agar in 1920. Matsuoka acquired several patents relating to agar production, but his business failed within a few years. The factory was sold to John Becker, an engineer, who made a number of important labor-saving improvements in the

Along the Atlantic coast of the United States a search for agar-bearing seaweeds began in 1942. *Gracilaria confervoides* (L.) Grev. was found in abundance of commercial value along the coast of North Carolina near Beaufort[5]. Late in 1943 the Van Sant Company at Beaufort, working with an affiliated firm, the American Chlorophyll Company of Alexandria, Virginia, began to produce agar. The Beaufort factory had been built for

[5] Humm, H. J. Science 96: 230–231. 1942.

other purposes, but since war had curtailed its original work, it was quickly adapted to produce agar exclusively. In 1945 the name was changed to Beaufort Chemical Corporation and its production capacity increased.

Exploratory work for agar resources continued along the Atlantic coast in 1942 and 1943 with financial aid from the War Production Board. A survey of the coast from Maryland southward, around the State of Florida and along the Gulf coast to New Orleans, resulted in the discovery of additional seaweed resources from which agar or an agaroid could be produced[6]. The greatest abundance of seaweed was found along the west coast of Florida south of Clearwater, especially in Tampa Bay. The most common species include *Gracilaria blogettii* Harv. and *G. foliifera* (Forssk.) Børg. The extractive of these species from the west coast of Florida is an agaroid, as it is inferior in gel strength to agar. Considerable quantities of *G. foliifera* from which agar can be produced were found also along the east coast in the Indian river between Daytona Beach and Stuart. The gel strength, however, is somewhat inferior to that of agar from *G. foliifera* of North Carolina.

FIG. 2. *Hypnea musciformis.* (*Courtesy Duke University Press.*)

Experimental and small-scale agar production took place on both the west and east coasts of Florida during the war. Experimental work was done at Citrus Concentrates, Inc., at Dunedin, and production on a small scale was undertaken by Sperti, Inc., near Jensen on the Indian River. However, significant quantities of agar were not produced in Florida before the end of the war, and apparently Florida production is still unimportant. An exclusive right to collect seaweed from the beds of known commercial value in the Indian river was issued to Sperti, Inc., by the State of Florida.

In 1943 a subsidy was received from the Office of Production and Research Development by Duke University and its marine biological laboratory at Beaufort, North Carolina, to expand a pro-

[6] Humm, H. J. Science 100: 209–212. 1944.

gram of research on Atlantic coast agar resources. One outcome was the discovery that a new type of agar can be prepared from the extractive of *Hypnea musciformis* (Wulf.) Lamour.[7] The important properties of this agar, gel strength and temperature of gelatin, can be altered or controlled over a wide range by addition of certain salts, sugars or other solutes.

Development of Agar Industry in Other Countries

Production of agar from *Ahnfeltia plicata* (Hud.) Fries and of an agaroid from *Phyllophora rubens* (L.) Grev. began in Russia about 1930. *Phyllophora*, abundant in the Black Sea near Odessa, apparently was the first to be utilized. *Ahnfeltia* is found in abundance in the White Sea, especially in the vicinity of Vladivostok, Archangel and Vladimir, cities of the far eastern provinces. *Ahnfeltia* agar is of good quality, but it is not produced in as great a quantity as *Phyllophora* agaroid. As in the United States, these pre-war Russian industries immediately expanded in 1942. Russian scientists have published many reports on technology, manufacturing processes, chemical nature and properties, and on the various uses of Russian agar and agaroid.

In 1942 production of agar began in many other parts of the world, particularly in Australia, New Zealand, South Africa and India. An abundant supply of *Gracilaria confervoides* in Australia near Sydney, in Moreton Bay, and in Big Lake near Yamba provides raw material for a thriving industry. Over 40 tons of agar were expected to be produced during 1946[8], and plans call for expansion to a capacity of several hundred tons per annum within the next few years. Australia consumed about 71 tons of agar in 1938, all of which was imported from Japan. Australian *Gracilaria* agar is said to be satisfactory for culture media and to have somewhat greater gel strength, elasticity and transparency than pre-war Japanese *Gelidium* agar. Another report states that Australian agar has a slighty lower gel strength than the Japanese product. The temperature of gelation of the two is about the same (37° to 42° C.).

As early as 1939, government laboratories in New Zealand began to consider the suitability of domestic seaweed for agar production. Four species, *Pterocladia lucida* (R. Br.) J. Ag., *P. capillacea* (Gmel.) B. & T., *Gelidium caulacantheum* J. Ag. and *Gracilaria confervoides*, have been tested.[9] The first mentioned species is the principal source because of its greater abundance, large size and relative ease with which it can be collected and processed. *Pterocladia* agar is said to be as good as Japanese *Gelidium* agar in all important properties, and better with respect to gel strength. New Zealand is apparently producing as much agar as was consumed in the islands in pre-war years.

The agar industry developed in South Africa in 1942, utilizing the cosmopolitan *Gracilaria confervoides*[10]. Other species, including *Gelidium cartilagineum* and *Suhria vittata* (L.) J. Ag., have been found to contain agar but do not occur in sufficient abundance or are difficult to collect in quantity. *Gelidium pristoides* (Turn.) Ktz. and *Hypnea spicifera* (Suhr) Harv. were also tested and found to produce a weaker gel than the others.

In 1941 the Laboratories of Industrial and Scientific Research in India investi-

[7] DeLoach, W. S., Christine Wilton, H. J. Humm, and F. A. Wolf. Bul. 3, Duke University Marine Station. 1946.

[8] Makaroff, A. Food Ind. 18: 1545–1548. 1946.

[9] Moore, Lucy B. New Zealand Jour. Sci. & Tech. 25: 183–209. 1944.

[10] Isaac, W. E. Jour. So. Afr. Bot. 8: 225–236. 1942.

gated the possibilities of agar production from a species of *Gracilaria* (*confervoides?*) that grows in abundance along the coasts of Travancore State[11]. Two grades of agar, commercial and bacteriological, are produced. A yield of 43% of the dry weight of the seaweed is claimed.

In Italy the presence of agar in a red alga of the genus *Spyridia* was reported in 1940, although no reference was made to its abundance or utilization[12]. A weak gel was also prepared from *Grateloupia* that was said to be suitable for bacteriological purposes in a concentration of five percent.

Mexico has been an important source of raw material for California agar factories for a number of years. During the war, however, a factory was completed there. Agar production has been reported also in the Dutch East Indies and Straits Settlements.

Uses of Agar

Agar was originally used in the Orient solely for food. Before the discovery of its value as a gelling agent for bacteriological culture media in 1882, small quantities of it were shipped from Japan to Europe where it was used principally in making jellies or blanc mange. As a result of her experience with agar as a substitute for gelatin in the kitchen, Frau Fanny Hesse, the wife of an associate of the famous German bacteriologist, Robert Koch, suggested a similar substitution for culture media[13]. The idea was communicated to Koch who discovered that agar had many advantages over gelatin for culturing bacteria, and he published his observations in 1882. Soon thereafter bacterologists everywhere were using agar, and this new use led to a rapid increase in the quantities exported from Japan. The use of agar in bacteriology is still its most important use with respect to human welfare, although only about 15% of the agar consumed in the United States during the ten years before the war was for bacteriological purposes.

Western peoples became familiar with agar first as a gelling agent for food in place of gelatin, and later through its use in culture media. As a result of this introduction to America and Europe, many other uses soon developed. Today the uses of agar comprise a long and varied list, most of which were developed in America. New uses are constantly being announced. A detailed discussion of agar uses has been published by Tseng[14].

In Foods. As an ingredient of food, agar is rapidly gaining in popularity with manufacturers of frozen desserts, confections and baked goods. Large quantities are now used by bakers in fruit cakes, pie fillings, icings, meringues and certain types of bread. In fruit cakes agar is valuable as an agent for retaining moisture over long periods of time. In icings and frostings it prevents absorption of moisture during damp weather, with resultant stickiness, and prevents hardening during dry weather. In meringues and pie fillings it serves as a gelling or stiffening agent.

In sherbets and water ices agar is an excellent stabilizer. For chocolate milk, carrageenin is the best known stabilizer, while with ice cream, sodium alginate is preferred.

Agar is frequently used in cheeses, especially those of the Neufchatel type in which it reduces exudation of whey, renders the product easier to cut and gives it a firmer texture. Agar has been

[11] Bose, J. L., *et al.* Jour. Sci. & Ind. Res., India. 1: 98–101. 1943.

[12] Cioglia, L. Ric. Sci. Pro. Tecn. Econ. Naz. 11: 179–181. 1940.

[13] Hitchens, A. P., and M. C. Leikind. Jour. Bact. 37: 485–493. 1939.

[14] Tseng, C. K. In J. Alexander, Colloid Chemistry, Theoretical and Applied. 6: 629–734. 1946.

recommended also as a means of increasing the digestibility of cheeses.

Probably as much agar is used in confections in the United States as in culture media, especially for making jelly candies and marshmallows, but in other types of candy as well.

In mayonnaise and salad dressings agar may be used as a stabilizer and thickener. In canned meats, especially fish, poultry and tongue, agar or an agaroid is used to prevent the product from becoming mushy as a result of vibration in transit. Gelatin is less satisfactory because it melts during warm weather. Agar also prevents certain meats from causing a de-tinning of the inside of the can and subsequent darkening of the product. One of the principal uses for agar in Australia and New Zealand is in canned meats for export.

Agar is often used in place of pectin for making jellies, jams, marmalade and preserves. It does not require a certain proportion of sugar and fruit acid to gel, as does pectin. However, the acidity of the fruit juices or pulp must not be greater than pH 5.5, or agar will be hydrolyzed when heated and fail to gel. For gelling acid substances, an agar solution should be prepared separately in water and mixed with the fruit product after both have begun to cool.

When used in foods in place of gelatin, agar offers the following advantages: it solidifies quickly, it does not have to be refrigerated, it will not melt at room temperature, and only about one-eighth as much agar is required.

Medicinal Uses. Agar is best known to the layman as a remedy for constipation. For such use it is best taken in granular form with cereals or simply as a suspension in water. As a gel it is less effective. Its value in constipation stems from the fact that agar is virtually indigestible by man; hence agar particles constantly absorb moisture and swell as they pass through the body, providing an ideal form of bulk to promote peristalsis and elimination. Agar has been highly recommended as a therapeutic agent for chronic constipation in children. It is often added in granular form to bread, biscuits, cookies or cereal for this purpose.

Pills of various kinds are often coated with agar, especially where it is desirable to time or delay dissolution of the capsule or coating, or where there is need for a controlled rate of release of the medicinal agent.

Fig. 3. *Suhria vittata.* (*Courtesy New York Botanical Garden.*)

In Dentistry. Agar is used as the principal ingredient of a compound used by dentists to make impressions for plates. Agar is present as a gel in high concentration in this product. It is melted and poured into the mouth at a temperature that does not burn. Gelation occurs, however, at a few degrees warmer than body temperature. The

solidified mold can be bent or somewhat compressed in removal and the elasticity of agar causes it to resume the proper shape again. Agar is used in a similar manner in preparing molds for artificial hands and in other prosthetic work, and by sculptors for making impressions.

In Cosmetics. Agar often serves as a base for greaseless creams of various kinds, to stabilize emulsions, and to control moisture content in tooth pastes,

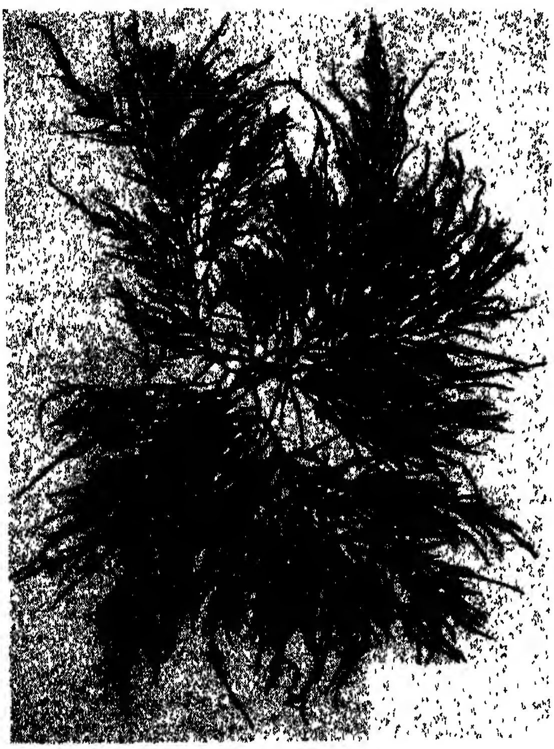


FIG. 4. *Agardhiella tenera.* (*Courtesy New York Botanical Garden.*)

shaving creams, hand lotions, deodorants, sunburn creams and other preparations.

Industrial Uses. In the manufacture of tungsten wire for light bulbs, agar is used as a suspending agent for graphite in a die-lubricating compound. It has been used in place of gelatin in photographic emulsions in which it has a number of advantages, but has never been widely used, probably because of the lack of uniformity of imported agar. Esters of agar are used, however, on the backing of films to prevent curling and reduce halation. These coatings wash off during developing.

Agar is used in hectograph duplicators, as an activator in nicotine sprays, in the electroplating of lead, in batteries for use in boats, and to coat humus particles for the marketing of nitrogen-fixing bacteria.

Agar and agaroids have been used to some extent for clarification of liquids such as wines, beer and liquors. In the Orient, it serves as a sizing for certain types of paper and fabrics.

In Science. In addition to its highly-important role in bacteriology, agar is one of the most important substances in studies on the physics of hydrophilic, gel-forming colloids. In chemical laboratories it is used to cause flocculation of barium sulfate precipitates. It is valuable to the microtechnician as an embedding medium for small pieces of plant or animal tissues that might otherwise be lost in solutions, and for cutting material with a freezing microtome. In studies of plant hormones, agar is used as a vehicle for the test substance in the *Avena* coleoptile method.

Manufacturing Methods

Since agar is readily soluble in boiling water, it can be extracted easily from seaweed. The resulting agar solution will form a firm gel when cool if the proper proportion of seaweed and water is used. Separation of the seaweed residue from the agar solution can be accomplished by simple straining, but removal of fine suspended matter is more of a problem because the viscosity and colloidal nature of agar, and the necessity of keeping the solution hot, make it rather difficult to filter. Filtration removes only the suspended impurities.

Soluble impurities can be removed from agar by freezing the gel and allowing it to thaw. As freezing occurs, most

of the water of hydration held by the agar micelles separates as free water. Upon thawing, water thus freed separates from the agar and takes with it the same percentage of soluble impurities as water lost from the original gel. The proportion of water set free varies somewhat with concentration of agar and species of seaweed from which the agar was extracted. Usually from 75 to 90% of the water is lost. Freezing and thawing are important steps in agar manufacture because of the two-fold effect: partial dehydration and a good degree of purification. The water remaining in the agar is removed by drying in the sun or in hot air. With agaroids, freezing and thawing are usually not practicable because so little water is lost.

American Factory Methods. A weighed quantity of dry seaweed adequate for one extraction is placed in a large tank of fresh water and washed by propellor agitation. It is then conveyed to a cooker. In California large pressure cookers are used; in North Carolina cooking is done in wooden tanks in which the water is heated by live steam. After two to six hours cooking, the agar solution is separated from the seaweed residue by straining and run into a storage tank in which a high temperature is maintained by steam coils. Usually the seaweed residue is cooked again and the resulting weak agar solution used as liquor in which to cook the next batch of new seaweed. Filter aid is added to the agar solution and it is forced through a filter press. In some factories a hypochlorite bleach is added to the agar just before filtration, but in others the bleaching agent is not added until later. From the filter press the agar solution is run into ice cans to cool and gel. After gelation has occurred, the agar may be chopped and then frozen, or it may be frozen in the cans without chopping. Blocks of agar ice are fed through a crusher and thence to a tank of water in which melting takes place. After melting is completed, North Carolina manufacturers drain the water off through a sieve and pump the wet agar to the drying room where it is spread on screens and dried by circulating hot air. It is hammermilled and pulverized and is then ready for market.

From the melting tank, California producers usually pump the agar-water mixture to a "dewaterer" which draws off the free water by vacuum, leaving the wet agar on a screen whence it is conveyed to a cylindrical stack drier through which a hot air current passes. As the moisture content of the agar flakes falls to 20%, they are buoyant enough to be blown to the top of the stack and are picked up by a screw conveyor. Some agar is marketed as flakes, but much of it is granulated by hammermill before it is packaged for use.

Japanese Method. The manufacturing process is similar in Japan but more primitive due in part to the low cost of labor. Dry seaweed as received by the factory is spread out in the sun again and alternately sprinkled with fresh water and allowed to dry until it is thoroughly bleached, a procedure necessary to obtain clean-looking agar where a filter press and filter aid are not used. Extraction is accomplished by open boiling, and often 20 to 40% of a cheaper substitute seaweed is added to the agarophyte, *Gelidium Amansii*[15]. The hot agar solution is strained through coarse and then fine mesh linen cloth and poured into wooden trays to gel. For shredded agar, the gel blocks are removed from the trays and cut into bars; then the bars are pushed through a grating to produce slender agar straws. These are spread on mats and allowed to freeze outdoors in the winter. When thawed and dried in the sun, the agar is pack-

[15] Tseng, C. K. In J. Alexander, Colloid Chemistry, Theoretical and Applied. 6: 629–734. 1946.

aged in the form of shreds. Since natural freezing is relied upon by most Japanese manufacturers, agar production is seasonal. Cooking is done only during late fall and winter. Seaweed is collected by fishermen during summer.

Physical Properties of Agar

Most investigators who have studied the physical properties or chemical structure of agar have worked with a commercially prepared product which they "purified". All commercially produced agar contains phycocolloids from a number of different species of seaweeds. Some Japanese agar may be as much as one-third extractive of a seaweed other than the principal agar source, *Gelidium Amansii*. Agar manufactured in America is not contaminated intentionally, but it is impossible for the manufacturer to free his raw material of all foreign seaweeds. Consequently, much of the data on physical properties is of limited value because of the influence on results by contaminating phycocolloids. To be reproducible and accurate, investigations must begin with the seaweed raw material, correctly identified by an algologist and carefully freed of all contaminating material before extraction of the phycocolloid is done. Any appraisal of the significance of literature on the properties of agar must take these facts into consideration.

Hysteresis. A phenomenon exhibited by agar to a remarkable degree is hysteresis, the lagging of response behind the application of some change causative of the response. *Gelidium* agar must be heated to about 90° C. in order to dissolve it in water. Once dissolved, gelation does not occur until the temperature has fallen to about 40° or lower. If the resulting gel is heated, it will not melt until the temperature is about 80°. Thus there is a range of at least 40° in which a solution of agar may exist either as a sol or as a gel. With North Carolina *Gracilaria* agar the range is only about 25°, since some samples begin to gel at about 60°, while the melting temperature is about the same as *Gelidium* agar.

The extractive from *Hypnea musciformis* is much more complex in its hysteresis behavior than any other phycocolloid known. In general, the temperature range between gelation and melting varies from 15° to 20°, a narrower range than for most phycocolloids. Since a solution of pure *Hypnea* extractive in distilled water apparently will not gel at any temperature in the absence of an electrolyte or some other solute, solutes, in addition to serving as gel-promoting agents, affect such characteristics as gel strength, temperature of gelation and melting, syneresis, viscosity of melted solutions, hysteresis and other physical properties. If potassium chloride is used to cause gelation, the temperature range between gelation and melting is about 16°; with rubidium or caesium chloride the range is about 18°; with dipotassium phosphate, 12°. Only preliminary observations have been made on the behavior of this phycocolloid.

Gel Strength. A recent study of gel strength of a variety of agars showed *Gracilaria confervoides* of North Carolina to produce the strongest gel[16]. If the gel strength given for this sample be assigned 100, the relative strength of other gels tested (all 1.5% agar) is represented as follows: California *Gelidium* agar, 69; South African *Gracilaria confervoides*, 52; Japanese *Gelidium* 42; California *G. confervoides*, 30; Australian *G. confervoides*, 26. Samples from which these gel tests were made are not necessarily representative, although a general trend is probably shown. Variation in gel strength of North Carolina *Gracilaria*

[16] Lee, C. F., and L. S. Stoloff. Spec. Sci. Rept. No. 37, Fish and Wildlife Service, U. S. Dept. of the Interior. 1946.

is such that the average is approximately the same as California *Gelidium* agar. Observations on gel strength of *Gracilaria foliifera* agar from the east coast of Florida indicate that it is about 90% as strong as the best *Gelidium* agar[17].

The remarkable effect of solutes on the gel strength of agar from *Hypnea musciformis* is such that gels can be prepared from this extractive that will possess as much as twice the strength, in equal concentration, of any other agar known, provided the proper solute is present. Many electrolytes are known to increase the gel strength of certain phycocolloids, especially carrageenin, but the relative effect is much less than with *Hypnea* extractive.

Syneresis. One of the characteristics of all gels is the tendency to slight shrinkage and a concomitant squeezing out of tiny droplets of water. Gels of both *Gracilaria confervoides* and *G. foliifera* typically exhibit greater syneresis than those of *Gelidium* agar. Syneresis of gels of *Hypnea* has been observed only superficially, but it is known to vary with the nature and concentration of solutes present.

The liquid that exudes from agar gels contains a higher concentration of solutes than were present in the original sol[18], except when certain mixtures of salts are present. As gelation occurs, agar particles are believed to grow in size and to form a vacuolate system in which solutes become more concentrated in the liquid phase because of hydration of the agar micelles. Syneresis represents a small portion of the liquid phase that is forced to the surface by contraction. Syneresis varies inversely with concentration of agar in a gel, while solutes affect both rate and volume of exudation.

Imbibition. Studies on the absorption of water by dehydrated agar have led to a better understanding of its physical properties and have shown that the principal factors that determine the extent of imbibition and swelling when equilibrium is finally reached are initial moisture content and the nature and concentration of solutes. As imbibition occurs, heat is evolved.

The longer an agar solution is heated at 100° C., the less will the agar swell after dehydration followed by soaking in water[19], but at the same time, ultimate swelling is also affected in a curious way by the initial water content[20]. Totally dehydrated agar swells relatively little, but swelling is progressively greater with greater initial water content up to about 313 mg. of water per gram of dry agar, where swelling is at maximum. Beyond this point a relatively higher initial water content results in relatively less swelling. At the point where the initial water content is about 554 mg. per gram of dry agar, swelling is slight and a change in optical properties has been noted. Agar sheets or disks are transparent with less than 554 mg. of water per gram, while with greater moisture content they are opaque. Further observations of this nature are needed on agar of known source and from different species of seaweeds.

Solutes, both electrolytes and non-electrolytes, have a pronounced affect upon the extent of imbibition of agar. Various acids and bases are said to have about the same affect upon swelling at a given pH, the maxima occurring at pH 3.0 and 11.0. In dilute solutions of neutral chlorides, the swelling of *Gelidium* agar is greater than in pure water, but

[17] Williams, R. H. Proc. Fla. Acad. Sci. 8: 161–170. 1945.

[18] Rossi, G., and A. Marescotti. Gazz. Chim. Ital. 63: 121–127. 1933; *Ibid.* 66: 223–227. 1936.

[19] Fairbrother, F., and H. Mastin. Jour. Chem. Soc. 123: 1412–1424. 1923.

[20] Clarke, B. L. Am. Chem. Soc. Jour. 47: 1954–1958. 1935.

if the concentration of chloride is about 0.1 N or greater the swelling is less than in water. Cations are of greater significance, but anions affect the process, especially in higher concentrations; both cations and anions exert an effect in the order of their place in the lyotropic series. The effect of ions upon the imbibition of *Gelidium* agar is apparently the reverse order of their affect upon swelling of *Hypnea* extractive. Agar exposed to ultra-violet radiation or x-rays swells less than untreated samples, probably because of partial hydrolysis caused by short wave length radiation.

Precipitation. If a melted agar solution is poured into a large volume of ethyl alcohol or acetone the agar is precipitated as a white fibrous mass. Alcohol-precipitated agar can be redissolved in cold water, if the precipitate is not permitted to dry, and a gel will form immediately following dispersion of the agar. If the precipitate is dried, it must be heated almost to boiling to redissolve. Precipitation by alcohol is a convenient method of purifying agar.

Agar sols are also precipitated by small quantities of tannin (as little as 1%) or by large quantities of very soluble electrolytes. Explanation of these phenomena is based upon the theory that agar particles are stabilized by both hydration and electric charge and that both these factors must be removed to effect flocculation[21].

Solubility in Organic Liquids. Agar can be dissolved in glycerin, ethylene glycol and other polyhydroxy alcohols. *Gelidium* and *Gracilaria* agars do not gel in these liquids unless at least a small amount of water is present. *Hypnea* extractive, however, forms a firm gel in the complete absence of water. Apparently the micelles of the *Hypnea* sol are more rapidly "hydrated" by molecules of the solvent. It seems likely that special uses for *Hypnea* extractive will be developed by virtue of its property of forming gels in such liquids.

Chemical Nature of Agar

In recent years much progress has been made toward an understanding of the chemical structure of certain seaweed polysaccharides which include many of those collectively called agar. To speak of agar as a single substance of certain (if known) chemical structure is probably a mistake. It must be assumed that each species of seaweed synthesizes a chemically different type of phycocolloid until it has been shown that phycocolloids from two or more seaweeds are chemically identical. Since the term "agar" is applied to extractives from many different species of seaweeds, the chemical structure of agar can be given only in general terms that apply to all agar-like phycocolloids, unless the species is stated from which the agar was obtained.

It has been shown that *Gelidium* agar and certain agaroids are a sulfuric acid ester of a linear galactan that exists in nature as a calcium salt. The galactan, a very complex carbohydrate, is composed principally of *d*-galactose units but also contains *l*-galactose. Agar is readily hydrolyzed by heating with a dilute acid, after which the solution will reduce Fehling's reagent and in which galactose can be detected. The calcium of the agar molecule can be replaced with other metals such as potassium or sodium or even by organic bases such as aniline and alkaloids. The resulting agar retains its fundamental properties but does not behave in precisely the same way as natural calcium agar. By this means the influence of the nature of the metal ion on properties of agar can be studied. It has also been found that the sulfate ion can be replaced by chlorine or nitrate without destruction of the gel-forming property of agar.

[21] Kruyt, K., and H. G. B. de Jong. Kolloid. Beihefte 28: 1–54. 1928.

Electrodialysis of agar removes all metallic ions leaving the free agar acid, a 1% solution of which was found to have a pH of about 2.4[22]. Neutralization of the acid restores its gelating property, but if free agar acid is heated, irreversible hydrolysis results.

The ash content of *Gelidium* agar varies from about 1.3% in highly purified samples to 3 or 4% in commercially prepared agar. Calcium sulfate is the principal constituent. The acid-insoluble ash is usually less than 0.5%, most of which may come from diatoms, either from the seaweed or from diatomaceous filtering material used in filter presses.

[22] Hoffman, W. F., and R. A. Gortner. Jour. Biol. Chem. 65: 371–379. 1925.

With the agaroid carrageenin and with *Hypnea* extractive the ash content is 20% or greater. Apparently the carbohydrate portion of the molecule is less complex in agaroids.

One of the ultimate goals in the chemical analysis of phycocolloids should be the chemical synthesis in the laboratory of substances with similar properties. When a chemist learns how to combine a simple sugar, a mineral acid and a base to form a carbohydrate ester with properties similar to those of agar, he will have shown the way toward the creation of a long list of products of value to human welfare.

Utilization Abstracts

Oiticica Oil. The oiticica tree, *Licania rigida*, grows wild and to a height of 50 or more feet along rich river banks in northeastern Brazil, where for many years the oil obtained from its nuts has been used as a lamp fuel and for medicinal purposes. "More recently, mixed with resins, it has been used successfully for caulking boats. Processing of the nuts was primitive. The natives hulled the nuts, crushed the kernels in a hand mortar, then mixed the resultant mass with water and heated the mixture. The oil coming to the surface was skimmed off, then treated with hot water for many hours to purify it".

Demands for oil engendered by World War I induced the erection of extraction apparatus in Natal, and the oil extracted was used chiefly in the local manufacture of paint. In 1927 a factory was set up in Rio de Janeiro, and in 1929 another at Fortaleza which has since become the center of the oiticica-oil industry. Improved processing has rendered the oil suitable for use in paints and varnishes for cement, marine and metal surfaces.

Subsequent publicity and a drop in importations of tung oil from China increased the exports of oiticica oil from Brazil from 88 tons in 1934 to nearly 11,760 tons in 1945, about 95% of which came to the United States. Oiticica, a fast drying oil, has thus attracted attention as a highly successful substitute for tung oil in paints and varnishes, and very useful also in linoleum, inks, moisture-proof fiber board, brake-bands and metallic soaps, and as an improver of elasticity in rubber base products.

The pecan-like fruit of the oiticica tree has a yellow to black kernel, containing about 60% oil within a shell that is dull greenish when ripe. The crops are gathered, wholly from wild trees so far, from January through April, *i.e.*, during the rainy season, and the work is a peasant occupation under very primitive conditions involving transportation on burros.

By establishing penalties for felling oiticica trees and for picking unripe nuts, by prohibiting exportation of the seeds, and by supporting experimentation in the growing of oiticica trees and in technological problems of the oil, the Brazilian government has given support to this rapidly developing plant product from Brazil. (*W. N. Small, Brazil 20(8): 14. 1946*).

Cinchona Plantation in the New World

The pre-war Dutch East Indies monopoly of cinchona bark, source of quinine—the world's great febrifuge—is being challenged by the prospective results of extensive experimental plantings of the trees in Guatemala.

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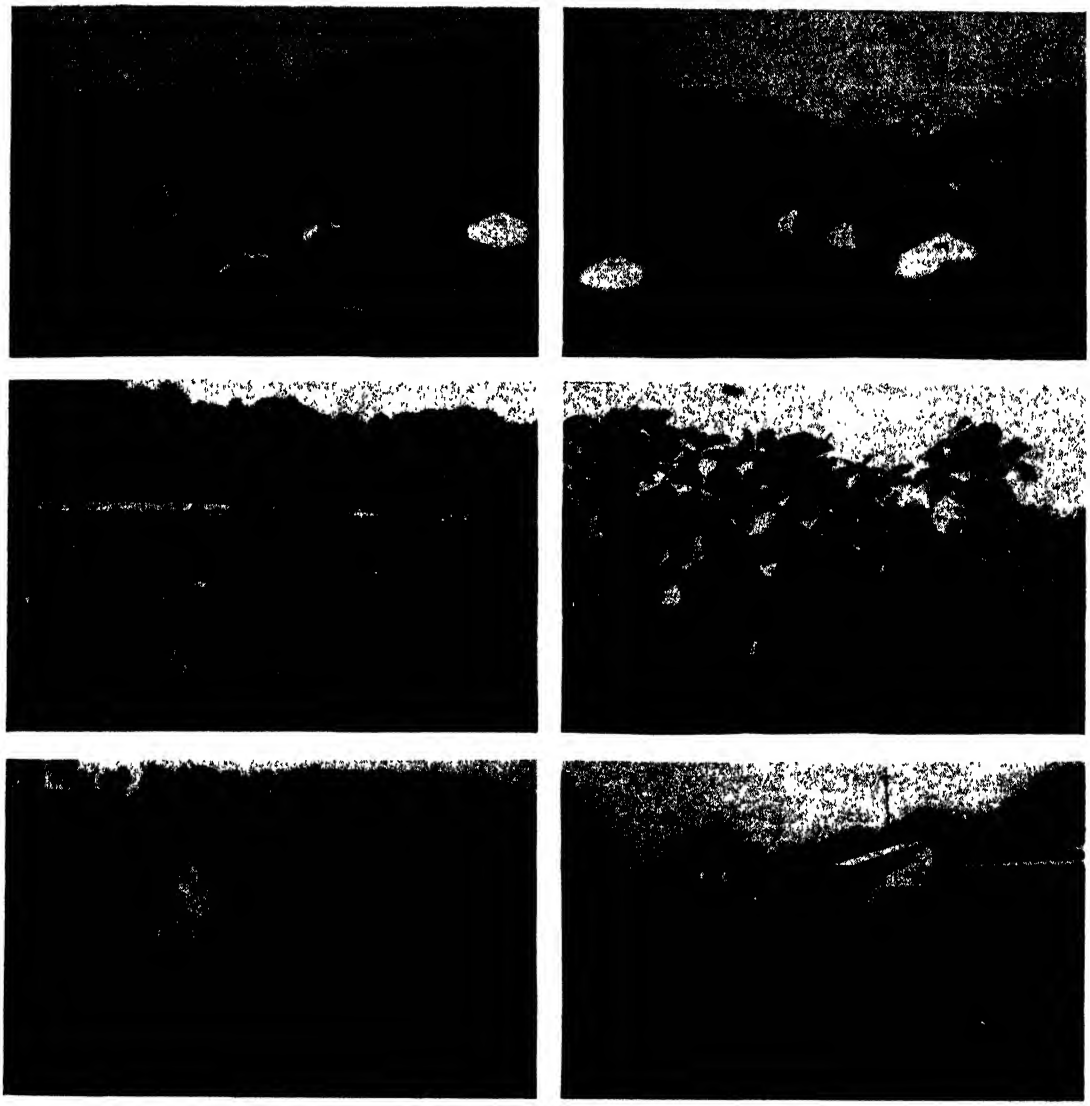
On the steep slopes of the extinct volcano Santa Clara, in southwestern Guatemala, a plantation may be visited where a fascinating experiment is taking place. It is an attempt to break the New World's dependence on the East Indies for a supply of cinchona bark, source of quinine.

In 1934, long before most people imagined the events of late 1941 and early 1942, when the cinchona plantations of the Far East were to be lost to the Japanese, American drug manufacturers were chafing at the quinine monopoly of the Dutch Kina Bureau. The shrewd cinchona planters of the Netherlands Indies had organized to protect themselves in their enjoyment of the fruits of their long and intensive research on the culture of this valuable tree. There had been many discouraging years of attempts at the establishment of plantations in the East, and many introductions of the trees were made from the New World. When finally, as a result of the introduction of the famous Ledger strain of cinchona from Bolivia, the plantations in the Orient became paying propositions, a supply of quinine to replace the rapidly vanishing wild product was assured. There followed a tremendous amount of research on methods of culture, harvesting of bark, and treatment and processing. Few other tropical crops have had such an amount of careful scientific work as cinchona. Then, in order to avoid over-production, with a consequent decline in price, the Dutch planters organized and effected a careful supervision of the amount of bark produced. The prices remained high, out of reach, of course, of the millions of impoverished malaria sufferers in the tropics, and the industry prospered.

During the years from 1900 to 1943 the amount of cinchona bark produced in America, the original home of the plant, was negligible. Small amounts of wild bark harvested in Bolivia were bought up by agents of the Kina Bureau. Occasional shipments of a low-quinine bark from northern Peru were sent to Europe for wine-flavoring. A few shipments of low-grade bark were made from Ecuador in recent years, and tiny dooryard plantations of the famous Succirubra variety of cinchona have existed for many years on the western slopes of the Ecuadorean mountains, but all without any influence on the world supply of quinine.

In 1934 Merck and Co., large scale American drug manufacturers, decided to attempt the promotion of cinchona cultivation in the New World. The technique adopted was to import seeds of desirable strains and to assist and encourage local coffee planters to undertake its cultivation. Guatemala was decided upon as the country in which to try the experiment. Though it may

have seemed almost hopeless to try to overtake and compete with the Dutch, with their 75 years of experience and operated well, but mistakes and discouragements were numerous and costly. Gradually a large number of strains of



Scenes at Finca El Naranjo, the Experimental Cinchona Plantation of Merck & Co. on the slopes of extinct Santa Clara volcano in Guatemala.

FIGS. 1 & 2 (*Upper left and right*). Church and laborers houses. FIGS. 3 & 4 (*Center left and right*). Seedlings and young trees of the Succirubra type of cinchona. FIG. 5 (*Lower left*). Two of the plantation buildings. FIG. 6 (*Lower right*). Quills of cinchona bark, stripped from trees, spread in a patio to dry in the sun.

research, as well as their tight organization, the company considered it a good long-term investment.

The planters worked hard and cooperated well, but mistakes and discouragements were numerous and costly. Gradually a large number of strains of cinchona from many sources* were accumulated and selection programs started. Experience was being acquired.

In 1939 Merck and Co. decided to go

further into the business and, under their auspices, Experimental Plantations, Inc., was organized. Finca El Naranjo, a large coffee plantation southwest of the beautiful Lake Atitlan, overlooking the Pacific slope of Guatemala, was purchased to be used for large scale experiments in the culture of cinchona. Together with the planters already engaged in the business they formed an organization for mutual assistance and cooperation in research called "Cinchona Cooperators of Guatemala". With the work already done by the planters, the selections of plant material accumulated, and with the experience acquired, there was available a firm foundation on which to broaden out experimentation on a much larger scale and even for practical production. The second world war, with the temporary loss of the Dutch colonies in the East, gave the enterprise just the impetus it needed. The planters were encouraged to broaden their operations. Experimental Plantations has acquired several smaller properties, as well as a large plantation in a wild and inaccessible part of Guatemala near the Mexican border and another in Costa Rica.

Finca El Naranjo is a large and thriving establishment. A staff of expert horticulturists and plant breeders with trained Guatemalan assistants live permanently on the place. There are comfortable houses for the staff. The climate is ideal, as the altitude is about 4,000 feet and cool breezes have a free sweep in from the Pacific. There are a shop and store, road and telephone connections with the rest of the country, and a thriving colony of local Indian laborers who are provided with a neat little village of sanitary and adequate houses. Also, and very important in the tropics, there is a clean, pure and abundant water supply from the slopes of the volcano above.

On the steep dissected slopes above the plantation headquarters are field above field of young cinchona trees of various ages. These fields, the plots and rows within them, and even many of the individual trees bear numbers or other designations. These are the keys to the careful records of the experiments kept in the offices.

There is an enormous nursery, with row upon row of beds of seedling trees, and literally miles of transplant beds. Grafting is performed to the extent of literally hundreds of thousands of plants in a season. This grafting of plants with a high quinine content but delicate constitution on rootstocks of vigorous weedy strains greatly reduces the hazards due to losses and poor growth.

The plants chosen for large-scale propagation are the products of a long and ruthless process of selection. Out of thousands of progeny of "mother trees" known for their high quinine content, only the very best are saved. As soon as the young trees reach an age where the quinine content of their bark is significant, samples of each are taken for analysis. Of the trees sampled, only the few with the very highest percentage of quinine are permitted to be the parents of the next generation. This process is repeated again and again. The very best trees are preserved and propagated vegetatively to form the clones, or asexually multiplied individuals, which are to be the basis of further experiments and of the commercial plantations to come. Much of the work of this selection process was accomplished by the original planters before the founding of Experimental Plantations.

Both before and during the war every effort was made by Merck and Co., the planters, the U. S. Department of Agriculture, and many individuals to bring together an enormous collection of kinds and strains of cinchona from every source available. Seeds were purchased or stolen in Java, brought from the more or less abandoned attempts at cinchona

ture references. Several references, especially from this hemisphere, deal with "roselle" when it was determined later that the plant material discussed was actually kenaf. It is true that plants of these two distinct species are quite similar upon casual observation, but, by close comparison, the differences as set forth in Table 1 are apparent.

Kenaf, usually an annual but under certain conditions a perennial plant, belongs to a large genus containing fiber-yielding species. The genus *Hibiscus* is in the family Malvaceae, of which cotton (*Gossypium* spp.) is probably the most important member. The *Hibiscus* genus is characterized by plants that generally have large showy flowers, the rose mallow (*H. Moscheutos* L.) and okra (*H. esculentus* L.) being representative American species. The plants of this genus abound in practically all countries, and to find a fiber list that does not include from one to several species is difficult.

The most valuable species of the genus is, according to Dodge (15), *Hibiscus cannabinus,* which, he states, is a native of the East Indies; some writers (25, 32, 40) are of the opinion that the plant is native to Africa, while another (45) says its home is Asia and Australia.

Miyake and Suzuta (33) have compiled a list of 129 world-wide names which have been given this plant. The Sanscrit name for the cultivated plant of ancient India, which produced Deccan hemp, was "nalita" (52). According to the first accurate information on kenaf fiber (43), the source plant is known in western India as "Ambari" (hence the names "Ambari fiber" and "Ambari" or "Ambaree hemp"), whereas in Madras it is known as "Palungi" and in Bombay as "Deccan hemp". In Hindustan (17) the plant is called "patsan", while in Bengal it is known as "Mestapat". The name "Kanaff" is used in Persia. It has been pointed out (26) that many of the names, such as "Indian hemp", "brown hemp", "Bombay hemp" and "Roselle fiber", were names for mixed-fiber products that were obtained not only from *Hibiscus* spp. but also from *Cannabis sativa* L., *Crotalaria juncea* L., *Abelmoschus* spp., *Urena* spp., etc. At the beginning of the twentieth century the pure fiber of *H. cannabinus* was called "Gambo hemp" or "Bimlihemp" (a shortened form of Bimlipatam hemp), and the name "Java-jute" had come into use.

In addition to the above names, the plant has also been called "wild stock

TABLE 1

COMPARATIVE DIFFERENCES BETWEEN HIBISCUS CANNABINUS AND H. SABDARIFFA

Plant part	*H. cannabinus*	*H. Sabdariffa*
Flower:		
Bracteoles	Not adnate to calyx	Adnate to base of calyx
Color of corolla		
Fresh	Pale yellow to sulphur	Pale yellow
Withered	Pale yellow to sulphur	Pale yellow with reddish tinge
Seed:		
Shape	Triangular, angles acute	Rounded-hemispherical, angles rounded
Surface	Dull gray with many yellowish brown, raised spots	Dull gray without spots
Hilum	Yellowish brown, relatively small	Brownish red, relatively large
Stem	Prickly	Unarmed

rose", "teel", "wild saur", "Hemp mallow", "Sunn Okro", "hemp-leaved *Hibiscus*", "Kanaf", "Bastard jute", "Deccani hemp", "Deckanee hemp" and "Deckanse hemp". Among some of the other names mentioned, the fiber products have also been called "Mesta fiber", "Dekanee hemp", "Jute of Madras", "Bimlipatam jute" and "Bimli-jute".

Varieties

Until 1911, when five varieties comprising eight agricultural types of *Hibiscus cannabinus* were selected and described in India (27), the kind of plant always referred to in the literature was the green-stemmed type with divided leaves. As a result of this comprehensive botanical investigation, the following varieties were named and typed:

"1. Variety *simplex*
   Type 1.—Stems purple; leaves entire with purple petioles.
2. Variety *viridis*
   Type 2.—Stems green; leaves entire with green petioles.
3. Variety *ruber*
   Type 3.—Stems red below, greenish above; leaves divided with green petioles.
4. Variety *purpureus*
   stems purple; leaves divided with purple petioles.
   Type 4.—Late, stems very tall and slender; leaves with narrow lobes of a diffused purple color; petals purplish.
   Type 5.—Early; stems short and robust; leaves green with broad lobes.
5. Variety *vulgaris*
   stems green; leaves divided with green petioles.
   Type 6.—Plants very early.
   Type 7.—Plants late; seedlings with reddish stems.
   Type 8.—Plants late; seedlings with green stems."

Work in Cuba (10) has shown that the *Hibiscus cannabinus* grown for fiber in this hemisphere is composed of two varieties: *viridis* (type 2) and *vulgaris* (type 8). As the seed which was introduced into Cuba from El Salvador was reported to have come originally from commercial plantings in Java, it is logical to assume that the varieties in Cuba are representatives of those grown in Java. Two of these, *viridis* and *vulgaris*, have been identified; the other, *purpureus* (26), has not been ascertained.

The following description of the two varieties in Cuba is presented for a basis of comparison:

PLANT.—Herbaceous annual of 3–7 months duration, depending on time of planting.

STEM.—Straight, simple, more or less glabrous but with prickles; 3–14 feet in height, depending on time of planting.

LEAVES.—Cordate and very shallowly lobed with serrated margins, mid-vein with one gland beneath near base of blade, petioles generally longer than the blades, with prickles slanting toward the blade; stipules linear and pointed.—*Hibiscus cannabinus* var. *viridis* (type 2). Basal leaves cordate and not lobed, 3-, 5- and 7-palmately lobed into narrow serrate parts, respectively, up the middle portion and 3-palmately lobed into narrow serrate parts at top of stem; mid-vein with one gland beneath near base of blade; petioles generally longer than the blades, with prickles slanting toward the blade; stipules linear and pointed.—*Hibiscus cannabinus* var. *vulgaris* (type 8).

FLOWERS.—Solitary, with short peduncles in axils of leaves; corolla large, spreading, thickened below and thin above, petals pale yellow to sulphur-colored with crimson to purplish center; epicalyx stiff, consisting of 7–8 bracteoles, 10–13 mm. long, which are free above, connate below, and inserted near base of calyx; calyx bristly, lanceolate, 29–31 mm. long, connate below the middle, 5-parted with one large gland near the middle; style rises through staminal column, one in number which terminates in 5 stigmatic branches; carpels 5, joined into 5-locular capsule, each locule containing 4 or 5 seeds; capsule bristly, globose, pointed; seeds glabrous.

The preceding descriptions indicate that these two varieties are alike in all external characteristics except shape of leaves. Investigations (46) on the percentage of natural cross-pollination in the different varieties have shown, how-

ever, that *viridis* is entirely self-pollinated, while in *vulgaris* cross-pollination varied from 2.6 to 3.9% in its various strains.

Observations on the two varieties in Cuba have indicated that they are composed possibly of a number of strains, in that there has been some variation in the period of vegetative development among plants. For example, in one particular planting there were a few outstanding plants which were green and had retained all their leaves, while, at the same time, the remainder had dropped most of theirs and seeds had matured. Similar observations have been made in Russia (3) where it has been found that the variety *vulgaris* consists of a number of strains differing by their length of growth period, by

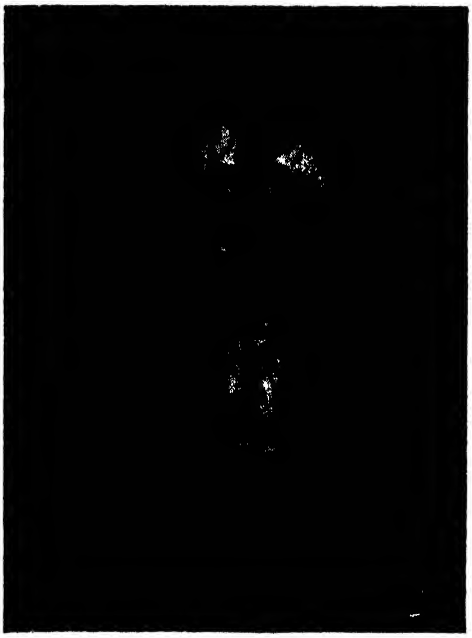


FIG. 1 (*Upper left*). 100-day-old kenaf ready for harvesting, planted in 8-inch drill rows, 30 pounds of seed per acre. FIG. 2 (*Upper right*). Kenaf may be harvested mechanically at the rate of approximately one acre per hour. FIGS. 3 & 4 (*Lower left & right*). 100-day-old kenaf stalks, cut and tied by a modified hemp harvester-binder, being loaded for transport to a de-fibering mill.

their habit of growth and branching, and by some other less important peculiarities connected closely with length of the vegetative period.

Work in Persia (41) has shown that the differences in strains of *Hibiscus cannabinus* are in the height of the plant, thickness of the stem, the color, and in the leaves and flowers. Strains were found with large and small seed capsules, and with large and small seeds. It was further noted that the earlier the strain, the closer to the ground the first flowering node was located; in the late strains, however, flowering began on the upper nodes.

The variations in strains within a particular variety might provide means of improving the plant for fiber purposes by selection in the field for one or two of the most obviously worthwhile characters, such as height of the first capsule and length of the stem. Some of the characters which an ideal fiber plant should possess are long thin stems, no branches, rapidity of growth and high fiber percentage with uniform length and strength. As this species is naturally self-pollinated, progress in breeding should be rapid and easy.

Cytogenetics

From the small amount of existing information there appears to be considerable disagreement regarding the chromosome complement of *Hibiscus cannabinus*. Some authors report the species to be a diploid, whereas others have found it to be a tetraploid. Ford (20) offers the explanation that possibly *H. cannabinus* may be composed of diploid and tetraploid races, as is its close relative *H. esculentus*, reported by Skovsted (44). The former and Narasinga Rao (37) found the chromosome complement of kenaf to be $2n = 72$, whereas the latter and Breslavetz *et al.* (5) found it to be $2n = 36$.

All crosses between the varieties and geographical races of *Hibiscus cannabinus* belong to the type of "congruent" crosses and are successful (31). From a study made by Medvedeva (31), the following data were obtained:

Plant material	$2n=$
H. cannabinus	
var. *purpureus*	36
var. *ruber*	36
var. *viridis*	36
var. *vulgaris*	36
var. *simplex*	36
H. Sabdariffa	
var. *altissima*	72

By treating the apical meristems of young diploid ($2n = 36$) kenaf plants with colchicine solution or with morphaline-colchicine emulsion, tetraploid ($2n = 72$) plants of the species were obtained (2). It was observed that the diploid and tetraploid plants resembled each other closely, but the latter showed a higher percentage of pollen sterility and had broader and thicker leaves. The offspring of diploid and tetraploid plants possessed about the same rate of growth. The theory was advanced that fibers of induced tetraploids may have greater length and diameter than those of the diploids from which they have been obtained (2).

Anatomical Portion of Plant Used for Fiber

The fiber obtained from the stems of *Hibiscus cannabinus* varies from five to ten feet in length (15). Each filamentous strand of fiber is composed of cells, their ends overlapping, which vary considerably in size but average about five millimeters long and 20 microns wide. These cells form collectively the principal part of the bast layer which gives strength and flexibility to the stem. This layer is the innermost portion of the bark and is located immediately outside the central woody cylinder and thin cambial layer.

FIG. 5 (*Upper*). 15-day-old kenaf in foreground; 100-day-old plants in background, ready for harvesting. FIG. 6 (*Lower*). The author examining kenaf fiber decorticated by a "Krupp" machine ordinarily used for henequen leaves.

Climatic, Photoperiodic and Soil Requirements

Kenaf is capable of adapting itself to a large variety of climatic and soil conditions (6), although, since it is sensitive to frost, it is best grown in tropical and subtropical locations. Early maturing strains (3) have been selected so that the plant can be grown under the conditions existing in central Asia. Extensive experiments (48) have proved that the northern limit of the plant is 45° north latitude. Kenaf is not uncommon in the lower Himalayas up to an elevation of about 3,000 feet (4, 7, 50). Areas where the plant is to be grown should be free or protected from strong winds (21, 53), since the growth is rapid and the plants get so tall that they cannot stand much wind. Extremely heavy rains are also detrimental in that they beat down the plants, and difficulty in harvesting results.

From 20 to 25 inches of rainfall over a period of four to five months is essential for the successful production of kenaf fiber (11, 26), this amount being less than is necessary for jute (18, 32). The wet period should be followed by a dry one in order that the fiber, after being extracted from the plant, may be dried and bleached in the sun. Although mechanical drying may, in the future, eliminate the necessity for sun-drying of the fiber, nevertheless, a dry period following the rainy season is necessary for the production of seed for successive crops of fiber. If rains occur during the time of seed maturation, the seeds germinate in the capsules before they can be harvested.

Along with the special requirement of climate, there is another factor which is of prime importance, inasmuch as the kenaf plant is photoperiodic and is influenced markedly by changes in length of the daily light period. This plant will not flower in Cuba (12), for example, until the length of the daily light period is shortened to approximately 12½ hours or less. A 12½-hour day length does not occur at that latitude (23° North) until the first part of September. Regardless of the time of planting, throughout the months from April to August, consequently, blossoming will not take place until September or October. This phenomenon in relation to time of planting for fiber and seed production will be discussed later in this paper.

A well-drained, sandy-loam soil, about neutral in reaction, with a considerable quantity of humus, appears to best meet the requirements of kenaf. On poorly drained soils the plant is seriously stunted and usually dies before producing flowers and seeds. Howard and Howard (27) pointed out that in certain sections of India kenaf is grown as a border crop on the edges of the fields where the soil is slightly raised and better drained than in the rest of the field. Use of light sandy soils for the production of kenaf is not recommended (21, 53), as plants growing in such soils bloom somewhat earlier, are short, and consequently give low yields of fiber. Since kenaf is very susceptible to nematodes, *Heterodera* spp., soils containing these organisms should be avoided.

Cultural Requirements

Kenaf responds well to good soil preparation (21, 27, 53). The soil should be deeply and thoroughly worked in order to provide a good medium for seed germination and to insure proper soil aeration for the seedlings that follow. Hard-pan layers close to the surface should be guarded against, since this condition retards growth and consequently reduces yields. Good soil preparation and cultivation are essential to the development of the plant because of its characteristic type of root system. Work in India (28) has shown that the tap root of kenaf grows comparatively

deep in the soil, and the development of laterals is not concentrated near the soil surface. Every effort should be made to insure a uniform germination of the seed and particularly an even stand of plants, so that there will be uniformity in the size of the stalks at harvest time.

A considerable quantity of humus in the soil is important for good production, and this can be supplied either in the form of manure or as green-manure crops (14, 26), both of which greatly stimulate the growth of *Hibiscus cannabinus*. *Crotalaria anagyroides* H.B.K., *C. usaramoensis* Baker, *C. juncea* L. and *Mimosa invisa* Mart. have been used successfully as green-manure crops. In Java (14) increases in fiber yields up to 50% have been obtained by using *M. invisa* supplemented with ammonium sulfate at the rate of 1,300 pounds per hectare (about 2.5 acres).

Time of Planting. Recommendations in the literature regarding time and rate of planting for fiber and seed are somewhat confusing, if not contradictory; but the discrepancies are the result of wide differences in environmental conditions and cultural methods employed in the various locations where the investigations were conducted. In view of the fact that the kenaf plant is extremely sensitive to changes in length of day, it is easily understood that the best time for planting in a location of a given latitude might not be successful in another location of a different latitude. Then again, the most suitable time of planting for fiber in one location might possibly be the best time of planting for seed production in another location, depending upon latitude.

Knowing the photoperiodic response of kenaf to varying periods of daylight, together with knowledge of the season of rainfall for a particular region, recommendations may be made as to the best time to plant for fiber as well as for seed production. In the production of any bast fiber it is highly desirable to have long clean stems free of branches or fruiting stalks which interrupt the continuity of the fiber. Planting of kenaf, therefore, must be done at the time of year when the days are of 12½ hours duration or longer and remain that way over a period of three to four months. This is necessary in order to prevent flower bud initiation until after the plants reach a sufficient height to insure adequate yields of fiber per area of land. Using Cuba as an example, the days with 12½-hour day lengths or longer comprise the months of April through August. Fortunately this period also includes the major portion of the rainy season. Planting for fiber as late as the middle of July to the last of August, however, does not give the plants sufficient time to grow vegetatively before flowering begins, and the crop does not reach ample height to produce profitable yields of fiber (13, 49). Planting as early as the first of April in some years would not be possible in Cuba, due to the fact that the rains might not begin until sometime in May. Therefore, plantings for fiber may be made from the beginning of the rainy

FIG. 7. Kenaf fiber as it comes from the decorticating machine.

season (April or May, depending upon local conditions) until the middle of July. Larger yields of fiber will be obtained from plantings made during the first part of this period than from plantings made later (13).

As the rainy season in Cuba generally ends about the last of October and as the day length is short enough to induce flowering during the months of September and October, the most reasonable time of planting for seed production is during the months of July and August. Higher yields of seed per plant have been obtained from July plantings than from August plantings (11). Planting in July, however, allows for approximately two months of vegetative development before flowering takes place; and, as a result, the bottom five- or six-foot portions of the stems are barren and contain no seed capsules. As plantings are made progressively later in the season, the portion of the stem which is barren becomes progressively smaller, but at the same time seed yields also decrease, due to the fact that the plants have a shorter period for development. If mechanical seed harvesting is to be used in the future, planting can be done any time during the months of July and August, depending upon the requirements of the machine and the nature of the plant material with which it will work to best advantage.

Distance of Planting. In general, the rather wide discrepancies in the literature with regard to proper distance of planting for fiber and seed production are the result, primarily, of the use of soils which varied considerably in fertility. For fiber production in Egypt (18) the seed is sown in hills eight inches apart, six seeds per hill, in ridges 21 inches apart. About 38 pounds of seed per acre are required using this method. After the seedlings have reached sufficient size, they are thinned to two or three per hill, according to the fertility of the soil. In Rhodesia (47) kenaf is sown by drilling in rows nine inches apart at the rate of 30 pounds per acre.

Workers in Java (14, 21, 32, 53) generally agree that the plants should be spaced six by six inches on the square, necessitating the use of from 13 to 18 pounds of seed per acre. Depth of planting is about one-half inch.

Recent work in Cuba (13) and El Salvador (49) has shown that the soils in those countries apparently can support a larger number of plants per unit area than soils in Java and some other parts of the world. Larger yields of fiber were obtained in Cuba from plantings made eight inches between rows and approximately two inches between plants in the row than from plantings with 16 and 24 inches between rows. This planting distance is equivalent to drilling the seed in eight-inch rows at the rate of 30 to 35 pounds of seed per acre. A somewhat larger area per plant is needed in El Salvador, as experiments there have shown that larger yields of fiber were obtained from plantings spaced two inches between plants in rows 12 inches apart than from several other planting distances tried (49). Planting by broadcasting at the rate of 38 pounds per acre has given good results; but, since a uniform stand of plants is particularly desirable, this method should be used with caution (53).

Since kenaf is harvested for fiber when the plants begin to bloom, a separate planting for seed is necessary for subsequent fiber crops. At fiber-harvesting time the custom has been, in many places, to merely leave uncut a portion of the field as a source of seed. This practice is not recommended, however, for two reasons. First, harvesting seed from a planting originally intended for fiber is difficult and costly. A fiber planting, if planted at the right time, grows vegetatively for a period of three

to four months before flowering begins. At blossoming time the plants may be nine to 12 feet tall, and the seed crop is borne on growth made subsequent to the initiation of blooming. At seed-harvesting time, therefore, the plants may have a total height of from 11 to 14 feet with, perhaps, the top two or three feet bearing seed capsules. Harvesting plant material such as this with a combine would be impossible. If, on the other hand, a separate seed plot is maintained, the time of planting can be adjusted so that plants of the desired height can be had at harvest time, with seed capsules at every node other than the basal foot or so of the stalk. In other words, depending upon the requirements of the harvesting machine used, the nature of the plant material with which the machine will work to best advantage can be controlled by the time of planting.

Using a portion of a planting originally intended for fiber as a source of seed is not desirable, secondly, for the reason that much lower yields of seed are obtained than from a planting made at the proper time and having a planting distance specifically for seed production. In previous discussion it was brought out how a plant with seed capsules borne practically the entire length of the stem, as compared with one having only from two to three feet of bearing surface, may be obtained by planting at a given time.

In Brazil (39) the planting distance used for seed production depends upon the method of seeding employed. When planting is done by hand, three seeds are dropped in each hill, 12 × 12 inches. However, when mechanical seeders are used, planting is done in continuous rows with a distance between rows of eight to 12 inches. Planting at this distance resulted in yields of only 180 pounds of seed per acre.

Choussy (8) states that in El Salvador kenaf for seed production should be planted between the middle of August and the last of September with 32 inches between rows and about 10 inches between plants in the row. Under normal conditions in El Salvador and in plantings which are well cared for, Choussy estimates the seed yield to be from 700 to 800 pounds per acre.

Dekker (14) in Java reports the planting distance used in that country to be 30 to 40 inches on a square, but no mention of yields is made from plantings of this nature.

Under Cuban conditions (11) 1,527 pounds of seed were obtained from a planting made late in August, using 20 inches between rows with one and a half inches between plants in the row. In comparison, plantings made 20 × 12, 24 × 14, 30 × 15 and 30 × 30 inches between hills yielded 597, 532, 371 and 343 pounds of seed per acre, respectively. It was pointed out that much larger yields of seed can be produced by planting in continuous rows 20 to 24 inches apart than by planting in hills at various distances. This planting method is readily adaptable to mechanization, as 12-row grain drills with eight inches between drills are already being used in Cuba in sowing kenaf for fiber production. In using these machines in planting for seed production, four rows, 24 inches apart, can be planted at a time by closing off the remaining drills.

Methods and Time of Harvesting. By planting in eight-inch drill rows, no cultivation or other care is required from the time of seeding to harvest. Kenaf is such a rank grower that it soon shades out weed competition. For seed production, where the rows are spaced farther apart, one or two cultivations may be necessary, depending upon seed bed preparation and weed population.

In harvesting, the custom has been to cut the plants by hand at ground level or to pull them up by the roots (6, 21, 43, 53). With one of the cut stalks used

as a string, the plants are tied into bundles, after which the tops with leaves are cut off. The slow and tedious process of harvesting kenaf by hand in this hemisphere is impractical and uneconomical because of the comparatively high wage rates. This problem has been solved, however, as a result of recent experimentation in Cuba (13). Mechanical harvesting investigations on a commercial scale, using a modified hemp harvester-binder, demonstrated that a crop of kenaf planted in eight-inch drill rows and which had grown to a height of 10 to 12 feet could be cut and bundled at the rate of an acre per hour.

Although some writers report to the contrary (14, 26, 43), the highest quality fiber is obtained when kenaf is harvested during the flowering period (18, 23, 50). As the percentage of fiber in the stem gradually increases until the time of flowering and then remains approximately the same (12), harvesting the plants either before or after this time would not be advisable. If done before flowering, lower yields of fiber are obtained, and if done after flowering, the fiber is of poorer quality (22, 50). With an increase in age of the plant, there appears to be an increase in coarseness and a decrease in lustre of the fiber. With the first formation of seed capsules on the stem, the fiber adheres to the pith more firmly than fiber in plants harvested earlier. It is generally agreed, therefore, that kenaf for fiber should be harvested during the flowering stage in order to obtain best results as far as yield and separation of the fiber from the stem is concerned.

Since the seed of kenaf matures progressively from the lower toward the upper portion of the plant, the best time for seed-harvesting, when done by hand, is when the seeds at the lower and middle portion of the bearing area are fully mature. The common method of harvesting kenaf for seed is to cut the plants by hand at the stage just mentioned and to shock them in the field for several days, so that seed at the top portion will have time to mature and cure before threshing. If harvesting by hand is delayed until all the seed capsules on the plant have reached maturity, then considerable seed is lost by shattering, especially from the lower portion of the seed bearing area. To thresh kenaf, the dried plants have usually been placed between large pieces of canvas and then beaten or flailed with long poles, after which the seed has been cleaned by winnowing. In Cuba and Honduras some threshing success has been achieved by running the dried plants through a rice thresher, and in El Salvador a coffee-threshing machine has been used for this purpose. It is expected that experimental trials to be conducted in Cuba this season will show the practicability of harvesting kenaf seed entirely by mechanical means. Since seed ripened on the plant before harvesting has proven to be better than that ripened in the shock (42), harvesting by combine would be desirable in that such a procedure would allow for seed-ripening on the plant.

Fiber Extraction

There are various ways to extract the fiber from kenaf stalks, all of which involve retting in water, except, of course, when power-driven decorticating machines are used. After the bundled plants have dried for two or three days in the field (26, 53), they are taken to a pond, irrigation ditch or retting tank and submerged in water. The length of the retting period, as reported in the literature, varies considerably from five to 22 days (6, 32, 40). This variation is caused, no doubt, by the greatly divergent environmental conditions under which the plants are grown, the differing stages of maturity of the plants at the time of harvesting, the different

kinds and temperatures of the retting water used, and the many other differing interrelationships that are not considered or controlled. The retting process is complete when the bark separates easily from the central woody cylinder and the fiber washes clean. At this stage the bundles of stalks are broken open and the fiber is stripped and cleaned by hand, after which it is dried in the sun. A skilled worker cannot strip more than 80 to 100 pounds of dry clean fiber in a day.

In El Salvador the cleaning process has been modified somewhat so that it is very similar to the method used in the United States for cleaning flax fiber. When the bundles of stalks are removed from the retting tank, they are shocked and left to dry in the sun. They are then passed between fluted rollers that revolve one above the other in opposite directions. This breaks up the central woody cylinder into little pieces. The material is then run through a beating machine which separates the wood from the fiber, leaving it quite silky and clean.

Large henequen—(*Agave fourcroydes* Lem.)—decorticating machines have been used successfully in Cuba to process kenaf. With the use of this machine the bundles of kenaf are brought directly from the field when harvested and put through the decorticator. The central woody cylinder, water and waste material from the plant are scraped away, leaving the clean fiber which is then dried in the sun for a day. The percentage of fiber varies with the age of the plant, but at the time of flowering the fiber comprises between 5% and 6% of the green weight of the stalks (13).

The capacity of the henequen-decorticating machine has been estimated at approximately 1,500 pounds of dried fiber an hour, which would require the stalks normally produced from about three-fourths of an acre. Consequently, to keep one machine in operation would require cultivation of kenaf on a large scale in order to be commercially practical. Experimental tests indicate, however, that the henequen-decorticating machine has promising possibilities for processing kenaf, and, since the harvesting is of short duration each year, the production of kenaf could well be worked into the henequen program.

Fiber Yield

The yield of fiber from *Hibiscus cannabinus*, as one would expect, is greatly divergent, depending upon the environment in which the crop is grown, the cultural methods employed, the conditions under which the stalks are retted or processed by machine, and other related factors.

Horst (26), in a study to determine the percentage of fiber in plants harvested at different growth stages and also the percentage of fiber in thick as compared with thin stems, found that in plants which were harvested to green (97 days after planting), a yield of 1.6% to 2% of fiber was obtained. When the plants were harvested at seed maturity, however, the yield of fiber amounted to 6.4%. He noted that the yield of high quality fiber was between these two figures, probably at 4% or 4.5%. The results of investigations in Cuba (13), on the percentage of fiber in different aged stems, showed a close parallel to data Horst obtained in Java. The percentage of fiber in the green defoliated stems increased from a low of approximately 2% when the plants were 40 days old to a high of slightly over 7% when the plants were 154 days old.

Fiber yields in India are reported to vary from 1,561 to 6,245 pounds per acre; in Senegal from 1,560 to 1,784 pounds per acre; while in Egypt average yields of about 3,123 pounds per acre are obtained (32, 40). In Nigeria (29) and Rhodesia (47) kenaf plantings on rich soils were reported to give a yield

of between 1,100 and 1,300 pounds of fiber per acre. In Cuba, by planting in eight-inch drill rows at the rate of 30 pounds of seed per acre, a planting made the first of May at the beginning of the rainy season yielded 5,805 pounds of dry clean fiber per acre (13). Plantings made at the same time in El Salvador, using a distance of 12 inches between rows and two inches between plants in the row, yielded only 1,224 pounds of fiber per acre. From these figures it must be concluded that the proper distance of planting and the subsequent yield of fiber are primarily dependent upon the fertility of the soil used in the production of kenaf.

The response of kenaf to the cultural methods discussed here exemplifies the possibility of producing this crop entirely by mechanical means. The comparatively high cost of labor in this hemisphere makes hand labor uneconomical, and mechanical seeders, harvesters and decorticators, therefore, will have to be relied upon if kenaf is to compete with jute fiber from India, a crop which is produced almost entirely by hand labor.

Disease and Insect Pests

In Java, Muller and van Eek (35, 36) report that the diseases which attack *Hibiscus cannabinus* are foot-rots which generally result in the death of the plant, and stem and leaf diseases which are of much less importance. Foot-rots are caused by *Pythium perniciosum* Serb., *Rhizoctonia solani* Kuehn, *Sclerotium rolfsii* Sacc. and *Phytophthora parasitica* Dast. The foot-rot caused by the last mentioned organism, according to these writers, is the most serious disease. It is described as a black basal rot, gradually merging into the sound tissue by way of an ill-defined water-soaked zone, and extending upward to a height, in severe cases, of three feet above ground level. In both these respects, according to Muller and van Eek (36), the *Phytophthora* rot differs from those due to *R. solani* and *S. rolfsii;* the discolorations induced are sharply differentiated from the healthy areas, and the height attained by the decay does not exceed two inches. Prophylactic measures should include soil sanitation, especially on sites of previous infection and around inlets of irrigation water.

Root knot nematodes, *Heterodera radicicola,* have been observed to be abundant in some plantings in Java (24). Likewise, the writer has seen considerable damage as a result of this pest in kenaf plantings in Cuba and El Salvador. Growth of infested plants is somewhat stunted and the leaves drop at or during the blossoming period. A rotation of crops, using one or more resistant types between successive plantings of kenaf, has proven to be an effective method of combating this pest.

Stem and leaf diseases of kenaf are of no great economic importance (36). *Phoma sabdariffae* Sacc. and *Cylindrocladium scoparium* Morg. cause some foliar spotting, sometimes accompanied by top rot, and local necrotic lesions on the stem cortex are produced by *Fusarium sarcochroum* (Desm.) Sacc., *F. coeruleum* (Lib.) Sacc. and *Diplodia* spp.

The only reference to insect pests of *Hibiscus cannabinus* which might cause some damage, especially to plantings grown for seed, is one made by Zegers Ryser (53). He states that *Dysdercus cingulatus* Fab. causes some loss by boring through the calyx and consuming the milky contents of the young seeds. No control for this insect is suggested except that the infested capsules should be removed and burned.

Characteristics and Uses of Kenaf Fiber and Seed

Kenaf fiber can be employed for the same purposes for which jute fiber is

used (15, 21, 26, 51). Several writers (16, 25, 27, 34, 50) agree that it is suitable for making coarse gunny cloth or sacking material, ropes and cordage of all kinds, fishing nets, floor matting, rug backing, *etc.* In some parts of India (16) the dry stalks of kenaf are split, tipped with a preparation of sulfur, and used as matches.

The ultimate fibers (single prosenchymatous cells of the bast), according to Biswis (4), vary from one and a half to four millimeters in length and are 12 microns in width at the middle. The thickness of the wall is four microns and the lumen is four microns broad. Biswis further states that the roughness and coarseness of the fiber are due to the nature of the encrusting substance, lignin. He found that the lignin is not entirely spread over the fiber, as it is in jute, which accounts for the difference in smoothness between the two fibers. In an experiment in which samples of kenaf and Bengal-jute were exposed two hours to steam at two atmospheres, followed by boiling in water three hours and again steamed four hours, the kenaf fibers lost 3.6% by weight, whereas the jute fibers lost 21.4%. He concluded that the kenaf fibers were tougher and stronger than jute because of the nature of the lignification.

Norman (38) states that the better known commercial fibers fall into two well-defined groups, one having only small amounts of xylan in the fiber cellulose, and the other having considerably more. The so-called fine fibers, such as flax and ramie, according to Norman, fall into the first group, whereas the coarser fibers, such as jute and kenaf, must be included in the second. In his study he found that kenaf fiber contained approximately half as much lignin as jute, 5.9% and 11.5%, respectively. Otherwise the two fibers were not very different in chemical composition.

In a study of *Hibiscus* fibers, Arno and Borschtschowa (1) found that two types of fibers exist in the stem of the plant, primary and secondary. They state that the division of the outer bast cylinder (the primary fibers) from the inner cylinder (the secondary fibers) is easily distinguished, since there are no anastomosing fiber bundles between the two cylinders. The primary fibers distinguish themselves from the secondary fibers by being firmer and more tightly packed together, by being glossier, more flexible, and by exhibiting other differences when used in the manufacturing processes. According to these authors, the differences in the two types of fiber are due to the origin of the fibers. The primary fibers (the first bast cylinder) appear to originate from the terminal meristem, or the vegetative point, whereas the secondary fibers arise from the cambium. The percentage of primary and secondary fibers in a given plant varies according to its height, but, on the average, there is about 38% primary fiber and 65% secondary fiber. With a decrease in stem thickness, an increase in the percentage of primary fiber was noted, whereas, on the contrary, with an increase in stem thickness, the percentage of primary fiber decreased. As far as spinning qualities are concerned, Arno and Borschtschowa preferred the early ripening varieties of *H. cannabinus*, since they were found to contain 56% primary fiber and 44% secondary fiber.

Kenaf seed yields up to 20% oil by weight of the seed, depending upon the extraction method used (29, 30, 32). It is stated that the oil is nonsiccative and, when refined, may be used for salads and cooking purposes. The oil, generally speaking, has about the same uses as cotton seed oil for which it could substitute with the advantage of having a somewhat milder odor (30). The residual cake may be utilized as cattle or poultry feed (29, 30, 32).

Summary

Kenaf, *Hibiscus cannabinus* L., is an annual or under some conditions a perennial plant belonging to the family Malvaceae. It is cultivated in many countries throughout the world for its bast fibers which are similar in chemical composition and physical properties to jute fiber of *Corchorus capsularis*. Five varieties, comprising eight distinct types, were selected and named in India several years ago. These five varieties, which appear to be representatives of the types of *H. cannabinus* grown in Persia, Russia, Cuba, Central America and other parts of the world, exhibit rather wide differences in the length of their growth period, in their habit of growth, and other peculiarities that are closely related to the length of the vegetative period.

Although kenaf appears to be adapted to wide variations in climatic and soil conditions, a well-drained, sandy loam soil, with a considerable quantity of humus, appears to best meet the requirements of the plant. From 20 to 25 inches of rainfall over a period of four to five months is essential to the successful production of kenaf fiber. Likewise for fiber production the length of the daily light period during the rainy season when the crop is grown should be of 12½ hours duration or longer in order to prevent flower bud initiation and subsequent blossoming until after the plants have reached a sufficient height to insure profitable yields of fiber.

For maximum yield of fiber per unit area of land, kenaf should be planted at the beginning of the rainy season. It is best planted by drilling in rows from eight to 12 inches apart, depending upon the fertility of the soil, at the rate of 30 to 35 pounds of seed per acre. For the production of seed, planting should be done from four to eight weeks before the length of the daily light period becomes shorter than 12½ hours. It is recommended that planting for seed production be done by drilling in rows 20 to 24 inches apart with two or three inches between plants in the row.

For highest quality fiber, harvesting is done shortly after the plants begin to bloom. The fiber, which is composed of cells forming collectively the principal part of the bast layer, or the layer which composes the innermost portion of the bark, is extracted by retting in water for several days or by large power-driven decorticating machines. Yields are variable, depending upon soil and environment, but generally a production of from 1,000 to 3,000 pounds of fiber are obtained per acre. A ton of seed may be obtained per acre if the proper cultural techniques are followed.

Hibiscus cannabinus is subject to foot-rot and stem diseases, the former being the most serious. Very few insect pests have been reported as attacking this plant.

Kenaf fiber may be employed in the manufacture of gunny cloth or sacking material, ropes and cordage of all kinds, fishing nets, floor matting, rug backing, etc. Kenaf seed yields up to 20% of oil which, when refined, may be used for salads and cooking purposes.

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twine, carpet thread, carpet yarn, sail cloth, homespuns, yacht cordage and oakum. To supply the demand much hemp was grown at home in the eighteenth and early nineteenth centuries, but never more than a fraction of what was needed. Cheaper foreign labor resulted in ever increasing importations from Europe and Asia until the maximum of 55,000 tons was reached in 1889. By 1900 competition from cotton and Manila hemp had reduced the American annual consumption of true hemp to less than 9,000 tons and importations of it to about 4,000 tons. In the 1920–1930 decade imports completely disappeared, and by 1933 the lowest figure of less than 50 tons of American grown fiber were produced. In the years just before the recent war this amount increased to about 600 tons yearly. Only two areas in Wisconsin and Kentucky were producing the material in 1940.

Then came World War II with increased demands for cotton and the loss of the Philippines, whence Manila hemp [*Musa textilis*] *had come.* As a remedial measure, to aid in meeting the demand for all fibers, the Hemp Division of the Commodity Credit Corporation of the U. S. Department of Agriculture was set up to revive domestic production of hemp fiber.

Through this agency 42 mills at a cost of more than $100,000 each were erected in hemp-growing districts of the United States, principally in Iowa, Minnesota and Wisconsin; least in Illinois and Kentucky. They obtained raw material from local farmers to whom seed was sold and machinery rented by the Federal Government These growers had to be registered under the Federal Marihuana Tax Act of 1937 and licensed under State laws. By 1944 only 17 of the 42 mills were operating, and in 1945 it was announced that they, too, would close. Contracts with growers expired at the end of that year.

Hemp is an annual crop, requiring 80 to 140 days from planting to harvesting, depending on moisture and temperature conditions. Only the stalks of staminate plants, which grow to ten feet in height, are used; pistillate plants are serviceable only as seed producers. The machine-harvested stalks are retted in the fields from two to eight weeks, during which time the fibers become loosened from the rest of the stalks. The material must then be stacked for winter curing, and the fiber later separated in the mill. Only 20% of the straw is fiber. A modern mill with the services of about 80 employees can separate about 10,000 pounds of fiber per day, whereas in olden days, when much highly skilled hand labor was needed for all operations, one skilled worker could prepare about 250 pounds daily. Previous to the recent short-lived, government-sponsored boom, Kentucky was the principal hemp-producing State, furnishing 75% of the nation's output; the remainder came from Wisconsin, Illinois, Nebraska, Missouri, Texas and California. (*J. H. Garland, Eco. Geog. 22: 126. 1946*).

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Technical Literature Reviews

Utilization Abstracts

Sorghum—*Its Production, Utilization and Breeding*[1]

A corn-like cereal grass which among its 400 known varieties produces broomcorn, the principal material used in the manufacture of brooms, and important edible grains of Africa and Asia—durra, kafir, milo, shallu, kaoliang, feterita and hegari.

R. E. KARPER AND J. R. QUINBY[2]

Botany

Sorghum, *Sorghum vulgare* Pers., is a large grass of many varieties, cultivated throughout Africa and grown extensively also in India, China, Manchuria and the United States of America. It is sown and harvested as well in Asia Minor, Iran, Turkestan, Korea, Japan, Australia, southern Europe, Central America, South America and some islands of the East and West Indies, and is generally distributed from the tropics to latitudes as high as 45 degrees.

Sorghum was so named because of its height, from the Latin word "surgo" which means "arise". In the United States, where the species was introduced, there are now 400 varieties, but less than 50 of them are of commercial importance. In Africa and Asia, where the species is indigenous, numerous other varieties exist. These varieties, even including Sudan grass (var. *sudanensis* (Piper) Hitch.), cross-pollinate readily and produce fertile offspring. Most of the differentiating characteristics are known to be genetic, and there is justification to consider all varieties as belonging to the same species. However, the genetics of the differences that distinguish such groups of varieties as the broomcorns (var. *technicum* (Koern.) Fiori & Paoli), kafirs (var. *caffrorum* (Retz.) Hubb. & Rehder), kaoliangs (var. *nervosum* (Hack.) Forbes & Hemsley), milos (var. *subglabrescens* (Steud.) A. F. Hill), shallus (var. *Roxburghii* (Hack.) Haines), sumacs (var. *angolense* (Rendle), *etc.* are not well understood. At least one notable attempt to classify some 3,000 forms into 31 species has been made in recent years.

Johnson Grass and Sudan Grass. All varieties of *S. vulgare* are annuals, but some mention should be made of a closely related perennial sorghum, Johnson grass, *S. halapense* (L.) Pers., that is a useful grass or a serious pest, depending upon whether it is of economic value under particular circumstances. Johnson grass resembles Sudan grass but is less robust and produces extensively creeping rhizomes. Since Johnson grass is difficult to eradicate, it becomes a troublesome weed when it invades cultivated land. It has twice as many chromosomes as the other sorghums and crosses with them only rarely. Hybrids between the two species are partially sterile. Johnson grass, while undesirable on cultivated land in the southern States, is an important forage grass and is cultivated in warm climates in both hemispheres.

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[2] Agronomist in charge of Sorghum Investigations, and Agronomist, respectively.

Sudan grass is a grassy counterpart of the coarser sorghums. The stems are smaller, the leaves narrower and tillering is more profuse than with other sorghums. The grassy nature of Sudan grass also shows in its lax heads and long narrow glumes.

Roots. The mature roots of sorghum are all adventitious, are fibrous and develop numerous laterals. The profuse branching and wide distribution of the root system is one reason why the sorghums are so remarkedly drought-resistant, but other factors also contribute to the drought resistance of the species. The plant grows slowly until the root system is well established, and at maturity the roots supply a leaf area approximately half that of corn. The plant can remain dormant during long periods of drought without death of the developing floral parts and can resume growth after conditions again become favorable.

FIG. 1. "Sourless", a popular forage variety of sorghum, the vigorous growth of which results in yields of four tons of dry forage per acre.

Stems. The stems are erect and solid and grow in height from two to 15 feet. There is a lateral bud at each node. In some varieties, one, two or three of the lowermost buds develop into tillers, and this tillering is not considered undesirable. However, development of lateral buds at the higher nodes, which results in side-branches that mature later than the main head, is objectionable. The length of the internodes determines the height of the plant, and double-dwarf, dwarf and tall varieties with the same maturity have equal numbers of leaves, the difference in their stature being due entirely to internode length and not to number of nodes.

Leaves. The leaves appear alternately on the stem, and leaf sheaths are

long and, in dwarf varieties, overlap. Varieties differ in leaf size, but all varieties have leaves somewhat smaller than those of corn, though similar in shape. Sorghum leaves inroll during periods of drought, and this characteristic contributes to the drought resistance of the species.

Flowers. The inflorescence of sorghum is called a "head" and is compact except in Sudan grass, broomcorn, shallu and a few sorgo varieties. The spikelets are of two kinds, sessil and pedicellate, the latter usually being staminate. Each sessil spikelet contains an ovary that develops into a seed after fertilization. The seeds are contained within glumes that cover them to a greater or less degree, and the glumes are usually black, red, brown or straw-colored. Sorghum flowers bloom during the early hours of the morning, and some reaction that takes place in darkness appears to be necessary for flowering. A sorghum head may contain as many as 6,000 florets whose anthers can produce up to 24,000,000 pollen grains. A panicle ordinarily blooms in five to seven days but consumes a longer time in cold weather. Sorghum is generally self-pollinated, but there is no barrier to cross-fertilization. When varieties are grown adjacent to one another, cross-fertilization of 5% is common. Sorghum pollen germinates immediately after being shed and retains its vitality less than an hour. The stigmas, however, are receptive for several days.

Grain. Sorghum grains are small in comparison to the grains of corn, and 12,000 to 30,000 are needed to weigh a pound. The seed may be white, red, yellow or brown, and the colors result from genetic complexes that involve the pericarp and testa. A large part of the caryopsis is endosperm, made up almost wholly of starch. Certain layers of some seeds contain considerable amounts of tannin, and sorgo varieties usually produce brown seeds of this sort.

Origin. The sorghums are considered to be of tropical origin. They are undoubtedly native to Africa, and it is possible that another center of origin may have occurred in Asia.

Photoperiodism. Sorghum is a short-day species, and this means that maturity is hastened when the light period of the day is short and the dark period is long. However, a difference in sensitivity to length of day occurs, and some varieties, such as broomcorn, are relatively insensitive. Hegari and milo are, on the other hand, quite sensitive to photoperiod. The differences in maturity that are common among sorghum varieties are a result of a difference in sensitivity to photoperiod or to a difference in critical photoperiod. Differences in response to photoperiod are genetic. Mutations have apparently taken place from time to time, and these have been used to extend cultivation of the species into higher latitudes. Insensitivity to photoperiod is apparently the result of thermal requirements, and so time of maturity in sorghum is influenced by both temperature and photoperiod.

Genetics. Sorghum has ten haploid chromosomes, and considerable genetic work has been done with the species in the United States, in India and in South Africa during the last 25 years. The inheritance of many genes is known, and four linkage groups, each involving more than three genes, have been reported.

Production

In the United States the acreage devoted to sorghum grown for all purposes increased to 20 million acres during the war period. This acreage is about double that grown prior to 1930. About 5% of it is devoted to the production of silage and about half the total acreage to the production of forage. In recent years almost half the acreage has been harvested for grain, and about two-thirds of the entire increase in acreage since 1930 has been devoted to sorghum

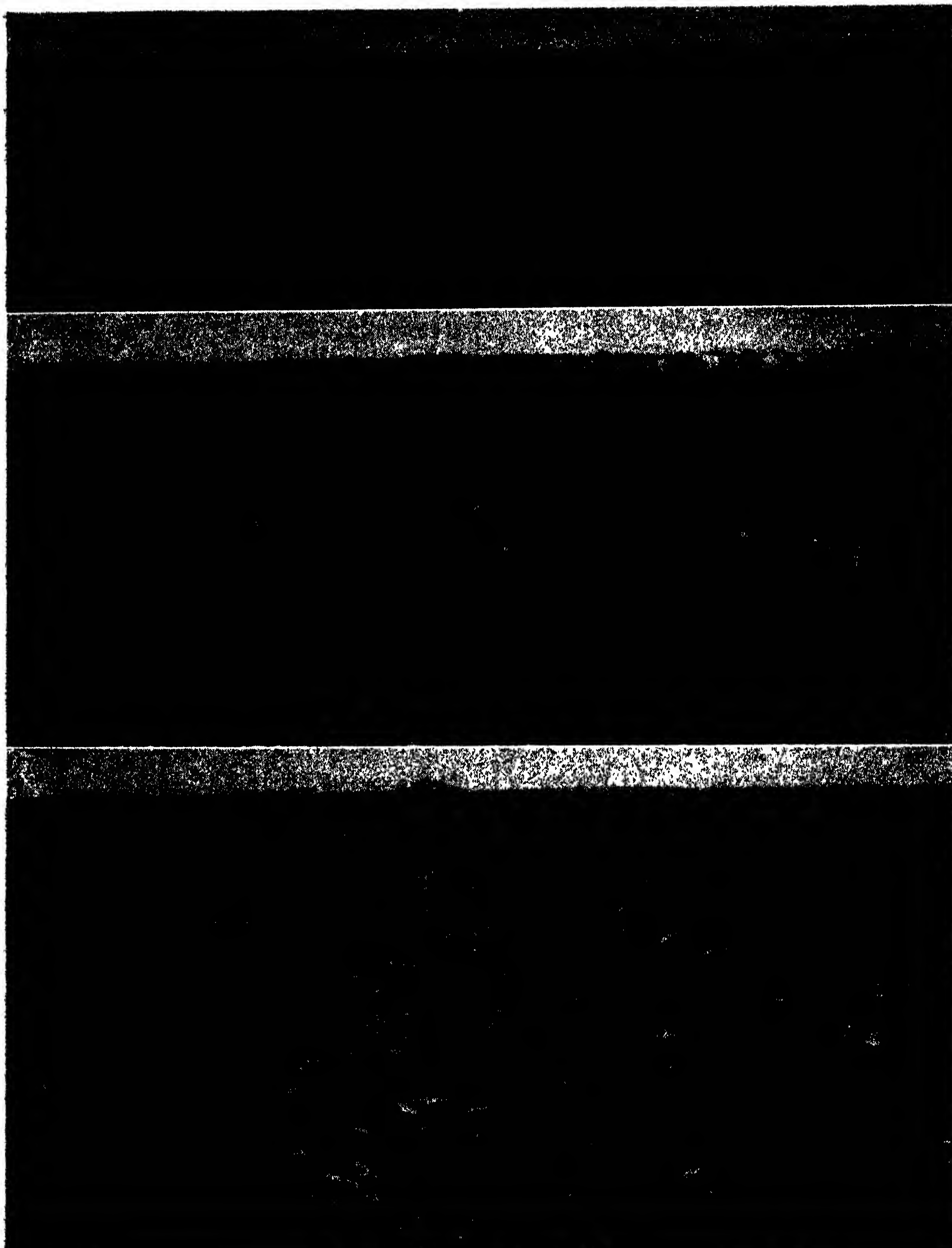


FIG. 2 (*Upper*). A field of harvested Early Hegari sorghum, a variety that is valuable for both grain and forage. This crop has been cut with a row binder and the bundles shocked. After drying in the shock the crop will be hauled and stacked, to be fed later to livestock, usually cattle. FIG. 3 (*Center*). A field of Plainsman sorghum that produced 65 bushels of grain per acre at Lubbock, Texas. The development of grain sorghum varieties of this dwarf stature has made this cereal of the Great Plains adapted to mass production. FIG. 4 (*Lower*). A field of the Plainsman variety, grown under irrigation and ready to be harvested with a combine harvester.

for grain production. Production of sorghum for sirup employs about 200,000 acres each year. Broomcorn occupies about 300,000 acres with concentrated areas of production in Illinois, Oklahoma, Colorado, New Mexico and Texas. Although sorghum, ranking in money value about with barley, is not one of the major crops in the United States, it is an important crop in the areas where production is concentrated. The newest area of extensive grain production is the Coastal Bend region of southern Texas. Production is concentrated in the Great Plains area from the Gulf to the Dakotas and in several interior valleys of Arizona and California. Sorghum is generally grown without irrigation except in Arizona, California and the South Plains area of Texas, but responds unusually well to irrigation. Where irrigation water is used, production is usually high, yields of 3,000 to 5,000 pounds of grain to the acre being common. Yields of unirrigated grain sorghum vary from a few hundred to 3,000 pounds.

Within recent years there has been a profound change in sorghum production in the United States that has been brought about because of the mechanization of the crop. This mechanization was possible because of certain inherited characteristics in the sorghum plant that were used by plant breeders to produce varieties of proper maturity and height so that they could be harvested with a combine harvester.

Since the species thrives in warm weather and is quite resistant to drought, sorghum is grown mostly in areas of the world where rainfall is insufficient for corn production.

Planting and Harvesting

Sorghums are grown in the United States from the Gulf of Mexico to South Dakota and from sea level on the Gulf to elevations close to or above 5,000 feet in parts of Texas, New Mexico and Colorado. Planting can be done on the Gulf Coast in late February, but is generally delayed until March or early April. The planting season progresses from south to north, and a favorable planting date in parts of Oklahoma or even further north is in July. Sorghums are grown, therefore, in environments where the days are 12 hours long and temperatures relatively low, in environments of 15-hour

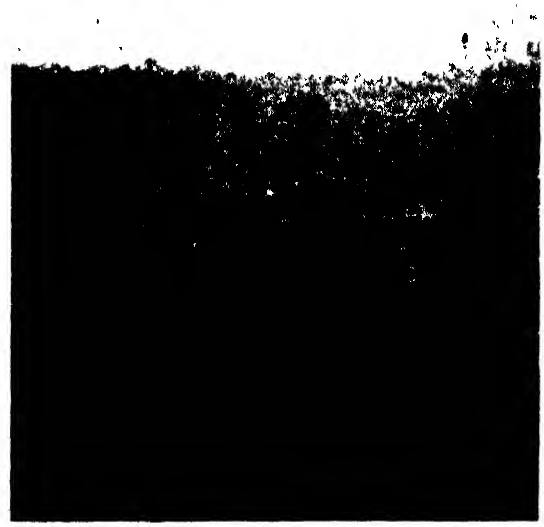


FIG. 5. The use of hybrid vigor in sorghum awaits the solution of problems in the economical production of hybrid seed. Blackhull kafir and Day milo here appear on opposite sides of their first generation hybrid which has consistently produced 40% more grain than the varieties in general use.

days with high temperatures, and in all combinations of day length and temperature between the extreme limits. The environment on the Gulf Coast somewhat resembles that of Bombay Province in India where the "rabi" crop is grown during the winter months. The latitude in South Dakota is the same as that of Manchuria. India and Manchuria grow varieties of entirely different adaptation, but in the United States

some of the same varieties are being grown in southern Texas and in South Dakota. This is possible because varieties that mature early regardless of environment are being grown. In all probability varieties that will fit into specific environments will be better adapted than varieties that are early maturing, regardless of environment, and breeding work based on this assumption is under way.

Crops grown for forage, grain, sirup and broomcorn are almost invariably planted in cultivated rows. Harvesting of the grain, which at one time was done largely by hand, is now generally performed with a combine. The crop grown for forage is usually harvested with a row binder, the bundles shocked in the field until dry and then hauled and stacked. The silage crop may be harvested with a row binder, but the use of field ensilage cutters is becoming more common.

The production of sorgo or sweet sorghum for sirup-making extends from the Gulf States to Wisconsin and from New Mexico eastward. Sorgo sirup is most commonly grown to supply home needs, with the excess to be marketed, but there are a few commercial factories. The average production of sirup is approximately 60 gallons per acre. The making of sirup from sorghum, whether done with the usual rather simple equipment found on farms or in a commercial factory, consists essentially in crushing the juice from the stalks, removing impurities from the juice and concentrating the juice by evaporation. The leaves are stripped from the green plants and the heads removed before the juice is extracted.

About two million acres a year are devoted to Sudan grass, most of which is raised as pastures for cattle, hogs and poultry. A small part of this acreage is used for seed and hay production. Sudan grass, except for the acreage harvested for hay, is usually planted in cultivated rows.

Sorghum grains are small, and small amounts of seed, usually two to ten pounds per acre, are used in planting. Seed production is unique in some ways. One thousand to two thousand fold increases in grain are common, and therefore it is not difficult to maintain seed. However, numerous varieties exist, and, since there are different seed colors and plant heights and since cross-pollination occurs frequently, varieties must be well isolated or other precautions taken if varietal purity is to be maintained. Sorghums are susceptible to many diseases, but fortunately many of them can be controlled by a rather simple operation. A number of different smuts infect most varieties, but all of them can be controlled by proper seed treatment and in some cases by the use of resistant varieties. Since sorghum is grown almost entirely on an extensive scale and the acre value is not great, production is usually not attempted under conditions or in areas where foliage and other diseases limit it to any great extent. Sorghum becomes infected with most types of diseases that are common to other grasses, and usually control measures are not used. Where insects are extremely injurious, the crop is not grown. Insects that infest the grain are the common ones that give trouble with other cereals, and are controlled in the same manner as in corn and wheat.

Sorghums are usually grown for grain only in areas where corn is not reliable because of high temperatures and limited rainfall, or in corn-producing areas where planting must be done later in the season than is favorable for corn production.

Sorghum is susceptible to frost, and in the temperate zone is grown only as a warm season annual. In tropical countries, however, it is grown throughout the year but always as an annual. In

parts of India where frost does not occur, sorghum is raised throughout the year, but different varieties are used there in the different seasons.

Utilization

Sorghum has many uses throughout the world. Most of the crop produced in the United States will probably always be used as livestock feed, but in certain parts of Africa and India sorghum is the most important human food. In some parts of Asia sorghum stalks serve as a substitute for wood as a fuel and are used in making baskets, furniture, mats, shelter and fences. Brooms made from broomcorn, a sorghum in spite of its name, sweep floors throughout the world. In truck-growing regions of the United States, sorghum crops are plowed under to restore humus to the soil; and in the semi-arid regions of the Great Plains sorghum is planted in narrow strips and the stalks left standing to prevent soil erosion by the wind. And finally there is a definite tendency for increased use of sorghum grain in industry, as we shall note later.

Livestock Feed. Sorghum silage is considered equal in value to corn silage, and the annual production in the United States varies between four and nine million tons on a green weight basis. Practically all the silage produced is fed to cattle. Sorghum forage is harvested from an acreage about eight times as great as that harvested for silage, and the annual production of dry matter is usually in excess of ten million tons. This forage, which consists of all the aboveground parts of the plant, is fed mostly to cattle but also to horses and mules. Sorgo forage usually contains less than 20% of grain by weight, but grain sorghum forage is usually about one-third grain. Sorghum forage contains slightly less digestible nutrients than corn forage but is more palatable and can be fed with less loss. Dry sorghum forage contains slightly above 50% digestible nutrients which consist of 8% protein, 2.5% fat and 45% nitrogen-free extract. Properly cured sorghum forage with a little protein supplement will maintain livestock in good condition throughout the winter with little or no grain supplement. Shredded sorghum forage mixed with concentrates gives good results with dairy cattle and, during the period of heavy feeding, with beef cattle. Shredding is done in "feed mills" on the farm and the practice is justified, since grinding the entire plant causes even the coarse stalks to be consumed. Sorghum stover, which is sorghum forage with the heads removed, is frequently used as a rough feed where only a maintenance ration is desired. Cattle will always be the predominant livestock in sorghum-growing regions, since they can make better use of rough feed such as sorghum fodder than sheep or swine.

SIX-YEAR ANNUAL AVERAGES OF ACREAGE AND PRODUCTION OF SORGHUM IN THE UNITED STATES 1940–1945

	Acreage 1,000 acres	Acre production	Total production
Silage	1,038	6.09 tons	6,317,600 tons
Forage	8,891	1.49 tons	13,221,209 tons
Grain	6,685	17.0 bushels	113,741,000 bushels
Broomcorn	277	320 pounds	44,549 tons
Sirup	192	60 gallons	11,574,000 gallons

Sorghum grain is similar to corn but contains slightly more protein and slightly less fat. Sorghum grain can be substituted for corn in almost all places where corn is used as livestock feed, and feeding results indicate that pound for pound the two grains have almost identical value. Sorghum grain, unlike yel-

low corn, contains very little vitamin A. The chief use for sorghum grain is as feed for horses, mules, poultry, sheep, swine and cattle. The grain, which contains about 12% protein, 3% fat and 70% carbohydrate, is not a balanced ration, and protein supplements must be added for best results.

ture are commonplace. It is estimated that Sudan grass pastures occupy two million acres each year in the United States.

Sudan grass, as well as other sorghums, is sometimes grown for hay. The hay is nutritious but it somewhat difficult to cure.

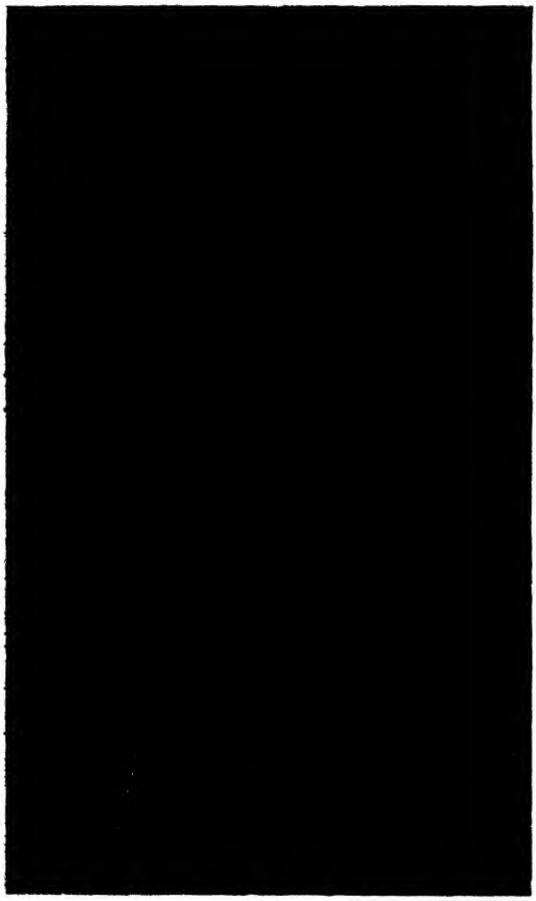


FIG. 6 (*Left*). Recessive genes in sorghum may be used to great economic advantage. This strain, containing two recessive genes for height, can be combine-harvested because of its low stature. Three other recessive genes produce tan plant color, white seed color and waxy endosperm. FIG. 7 (*Right*). Stalks of the Early Hegari variety which is a popular dual service form, since it produces large yields of grain and nutritious stover.

Sudan grass is an important pasture crop in many areas of the United States and fills an important need, since it grows during the summer period when other sources of pasturage are scarce or lacking. Dairymen make extensive use of Sudan grass, and beef cattle gains of 2.5 pounds per day on Sudan grass pas-

Human Food. It seems unlikely that sorghum grain will become an important part of the diet in the United States, but in a considerable part of India, China and Africa it is the most important food. In Bombay Province 75% of the acreage is devoted to the production of sorghum, and the grain in some form is eaten at

each meal. The grain is ground each day in the home, otherwise the flour would become rancid on account of the embryo not being removed, and is made into flat, thin cake similar to the "tortilla" made from corn by the inhabitants of Mexico. In India sorghum is considered to be a more complete food than rice or wheat, but the reason for the belief is not very obvious. However, in South Africa the excellent health of the native Bantu children is often ascribed to the kafir mush that they eat. Kaoliang is an important human food in much of northern China. In the pioneer days of the American West, grain sorghum or "gyp corn", used as bread or porridge, frequently allowed a family to remain on the land after drought or other calamity had destroyed the wheat or corn crops. The use of sorghum for human food could be expanded greatly in the United States if the necessity arose, and formulas and recipes for using sorghum were published by several States and the Federal government during the first world war. Breakfast foods in attractive forms can probably be produced from sorghums. Pop sorghum is a desirable confection, and many other possible uses are easy to contemplate. A "sugary" gene similar to that which produces sweet corn occurs in sorghum.

A dessert, similar in taste and quality to tapioca, is now being manufactured from a "waxy" type of sorghum starch. Importation of cassava from the East Indies ceased during the war, and importation from that area in the future is uncertain because of the need of cassava there as food. It seems likely that the growing of "waxy" sorghum varieties in the United States will continue and that 20 to 50 thousand acres will be devoted to this purpose.

Numerous varieties of sorghum are grown for human food in India, and the "rabi" crop, grown in the season corresponding to late fall and winter in the temperate zone, is the most relished by humans and livestock as well. An observation of sorghum grain received from India indicates that the grain is usually freer from spotting and similar injury than grain produced in America. Since little sorghum grain is consumed by humans in the United States no great effort has been made to select for grain quality. Unlike American grain varieties, which are short in stature, Indian varieties are almost invariably tall. In India where the acreage cultivated by each family is small and where fodder is an important consideration, no esteem is attached to dwarf stature.

Sorghum sirup, of which more than 12 million gallons is consumed annually in the United States, is used for both table and culinary purposes. Sorghum sirup is an important part of the diet of many low-income families in the southern States and is most frequently eaten with biscuits made from wheat flour or with corn bread and butter. The quality of the sirup varies with variety, and soil type also has a definite influence on quality. Light sandy soils produce the "mildest" and most desirable sirup, but some hardy individuals like their sirup "strong".

Broomcorn Brooms. Broomcorn brush consists of the panicle that is harvested when the seeds are in the milk stage. The seeds are removed in a simple thresher, the brush is cured and then manufactured into brooms. Tall varieties produce the longest brush which makes the larger as well as the better quality brooms. Whisk brooms are made from a short statured variety that produces short brush. The annual production of brooms in the United States is about 200 million. Broomcorn has been cultivated in Europe for 300 years and in the United States since Benjamin Franklin began its culture with seeds plucked from an imported broom.

Industrial Uses. In addition to its

use as livestock feed, sorghum grain can be utilized in industry also in almost the same way as corn, and such industrial use of it is increasing. It would be easy to over-emphasize the importance of this industrial use in view of the fact that a large part of the crop will always be consumed by livestock and frequently on the farms where the crop will be produced. However, an increasing proportion of the sorghum grain that enters commerce will be used industrially, and some mention of the possible industrial uses is justified. Most of the sorghum grain that will be processed industrially will be for the production of starch, dextrose, dextrose sirup, edible oil and by-products. A factory with a capacity of six million bushels annually is at present under construction at Corpus Christi, Texas, and will be in operation in 1948. The seed coat of the grain of certain varieties contains a valuable wax similar to carnauba wax [from the leaves of a palm, *Copernicia cerifera* (Arr.) Mart.] imported from Brazil for use in furniture and shoe polishes. This wax constitutes about 1% of the grain and can be an important by-product of industrial processing when methods for its recovery are worked out. A waxy type of starch that has been mentioned previously is produced by some varieties and is being used to replace cassava starch that was formerly imported for use in making tapioca, adhesives and as sizing for textiles. Alcohol is produced from sorghum grain in quantities quite comparable to those obtained from wheat and corn, and considerable sorghum grain was used for this purpose during the war. Sorghum has desirable malting characteristics, and its use as brewers' grits is expanding. During the present world shortage of food, a certain amount of sorghum flour, usually not over 10%, is being added to wheat flour for shipment abroad to starving populations. As has been mentioned previously, almost any use to which corn can be put in industry can be duplicated with sorghum.

Varieties

Varieties of sorghum in the world apparently exist almost without number. Many of the varieties are kept in existence in primitive communities and their culture is quite limited. On the other hand, vast acreages are devoted to single varieties in India, Manchuria, South Africa, Argentina and the United States. The innumerable varieties that exist in tropical regions will probably never become familiar to inhabitants of the temperate zones, since their heading is delayed in high latitudes by the long days that occur there so that the grain fails to mature.

In any particular region, however, it is possible to become reasonably familiar with the groups of varieties that have agricultural value and even to become somewhat acquainted with many forms from other parts of the world. Except in areas of the world where large acreages are devoted to the production of grain for the commercial market, no value is placed on short stature and uniform maturity. Most of the varieties that have been received from India, China, Turkestan and Central Africa are tall. Grain that is used for human food is generally without a brown testa and lacks a brown pigment in the pericarp that is associated with high tannin content. Kaoliang varieties, however, usually have seeds with a brown testa and a brown pericarp. Kaoliang varieties are not, however, extremely high in tannin content. Varieties are classified roughly into "grain" or "sweet", and it is becoming a general practice in the United States to designate the grain varieties merely as "sorghums" and the sweet or saccharin varieties as "sorgos". Most sorgos have brown seeds that are unpalatable, due to tannin content, and

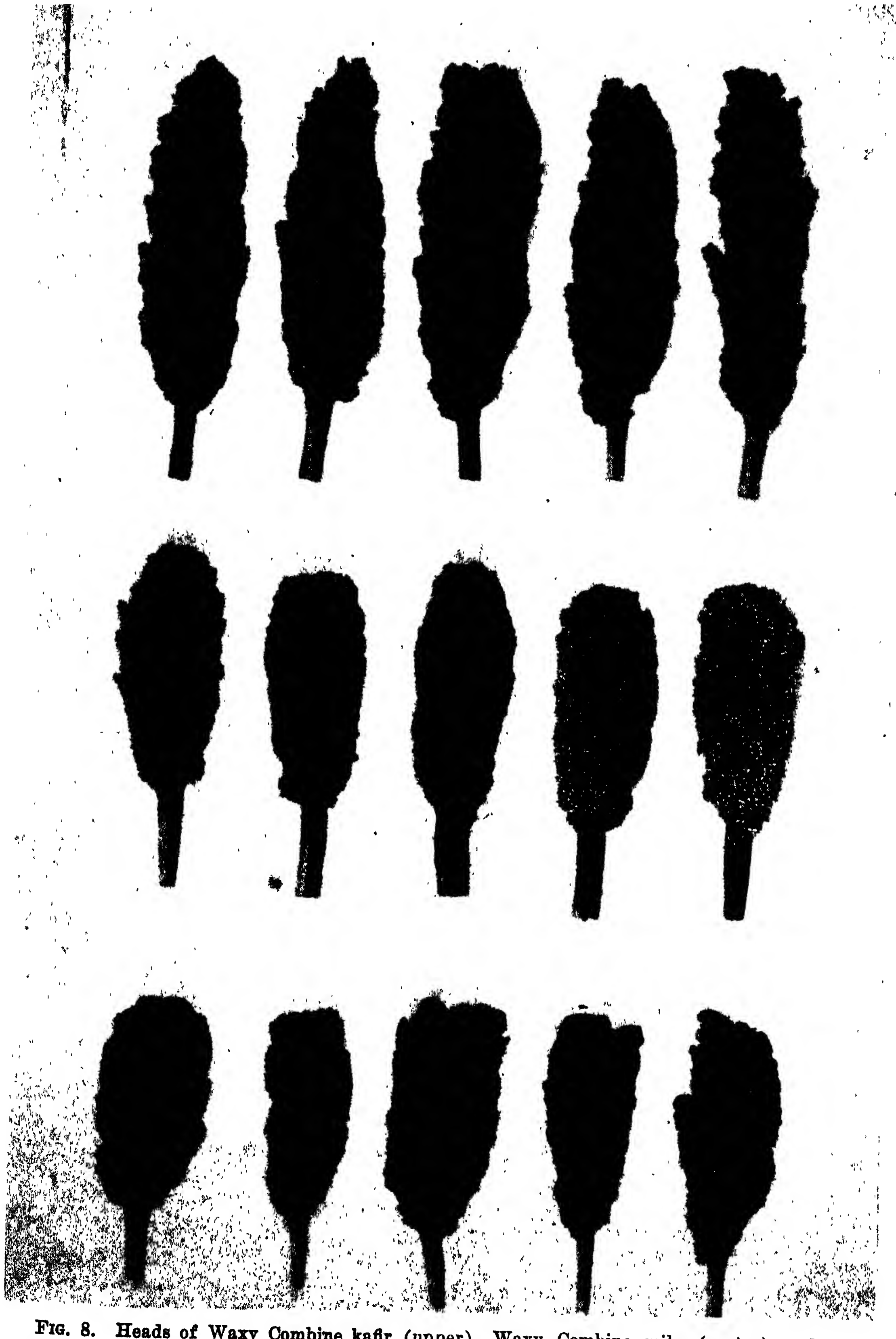


FIG. 8. Heads of Waxy Combine kafir (upper), Waxy Combine milo (center) and Cody (lower). These varieties produce seeds that contain a waxy type of starch used in the manufacture of tapioca, formerly made from imported cassava.

the grain of many do not thresh from the glumes.

The grain varieties frequently have a dry stalk that shows plainly, since the leaf midribs of such varieties are white. Juicy-stalked varieties, including all of the sorgos and many grain types, have leaves with opaque or translucent midribs. The common variety of Sudan grass has dry stems, but the improved variety Sweet Sudan has juicy stems.

A botanical description of sorghum varieties is not easy to accomplish, even for the varieties cultivated in the United States, primarily because they are so numerous but also because many of the distinctions are agronomic. Identification of varieties from grain and head samples is possible, and a classification that makes use of length of panicle branches, presence or absence of the testa, presence or absence of awns, grain

FIG. 9. Plats of Standard and Dwarf broomcorn. In harvesting, the tall variety is broken over with the plants from two rows forming a "table" about 4 feet high. The panicles are then cut from the stalks. Dwarf varieties are harvested by pulling the panicles from the stalk or cutting the peduncles just above the upper node of the stalk.

All broomcorn varieties have a dry stalk, but the stems of even the dry-stalked varieties contain some sugar.

There has been a drastic change in grain varieties during the last ten years in the United States but little change in sorgo varieties or in grain varieties that are harvested almost entirely in the form of forage. The change in grain varieties has come about to allow harvesting with a combine.

color and glume color was published as U.S.D.A. Technical Bulletin 506 in 1936. Mention will be made in the following paragraphs of the important varieties in the United States of the various types and of the distinguishing characteristics of the varieties. Several strains, usually of different maturities, exist of many of the varieties.

Sorgos. A list of the most important forage sorgos would include Sumac,

Sourless, Orange, Atlas, Honey and several Ambers. These varieties are mid-season in maturity with the exception of Honey which is late and the Ambers which are early. Sumac is readily distinguished by its compact heads whose seed is dark reddish-brown. Sourless has less pericarp color than most other sorgos and the seeds are buff in color. There are a number of Orange strains that all differ slightly in appearance, and the Kansas Orange strain has red glumes. Atlas, which came from a kafir × Sourless cross, has white seeds and looks much like a tall kafir but has sweeter stems. Honey is late in maturity, has light reddish glumes, and the seeds do not thresh from the glumes. Black and Red Ambers are early in maturity and have seeds that do not thresh from the glumes. The glumes of Red Amber are much darker red in color than those of Honey.

Important sirup varieties are Hodo, Honey, Sapling, Gooseneck and Orange. Hodo is so late in maturity that it can be grown only in the extreme southern portions of the United States. The seed of Hodo somewhat resemble those of Sourless. Honey, which has been mentioned previously, is the most important sirup variety in much of the United States. Seed production of this variety is low, and sirup producers need to maintain their own seed supply or have knowledge of the source of their seed. There are several strains of Sapling. This variety makes sirup of good quality but has a tendency to "sugar". Gooseneck is a late maturing variety whose peduncles recurve under certain conditions. This variety was more important in the past than at present because seed sources have almost disappeared. A number of strains of Orange are used for sirup-making, and Rox Orange is the variety used by one large commercial sirup-making company. Any of the sorgo varieties, of which there are a hundred or more grown in the United States, can be used to make sirup, but sirup quality varies with each variety.

During the expansion of the West after the Civil War, it was thought that sorghum might be a source of sugar. Much work was done by workers in the Department of Agriculture at Sterling, Kansas, and some promising varieties for sugar extraction were developed. Difficulties, that have now been overcome, prevented the early work from resulting in a sugar-producing industry using sorghum. At present the chief interest in sorghum for sugar manufacture grows out of the fact that sorghum matures earlier than sugar cane and that by using both species the period of sugar manufacture can be extended. At Meridian, Mississippi, sorghum is being grown for use in a nearby sugar manufacturing plant that operates on sugar cane most of the season. The varieties best suited to sugar manufacture are Collier, Folger, and Straightneck which is a strain of Sapling. As has been mentioned previously, these "sugar" varieties are not considered to be the best "sirup" varieties because of the inclination of the sirup of these varieties to "crystallize".

A number of grain sorghum varieties are used extensively for forage. These varieties will apparently stay in existence for this purpose, but commercial grain production will make use of only early maturing double dwarf varieties. The forage-producing grain sorghums include Hegari, Early Hegari and Blackhull kafir. At high latitudes or in the northernmost sorghum-producing areas early maturing varieties of kafir derivation are in use. Hegari and Early Hegari are similar except for a difference in time of maturity. These two varieties are most palatable to livestock, even though the stems are not very sweet. Both varieties grow to be four to six feet tall, produce numerous large

leaves, and tiller considerably. The seeds are chalky-white and have a brown testa that does not show through the outer layer of the pericarp. Blackhull kafir grows to be four to six feet tall and tillers very little. The heads are long and erect, the seeds white, and a testa is lacking. Varieties with local adaptation are numerous, and there is reason to expect many varieties to remain in existence, even though they occupy only a relatively small acreage.

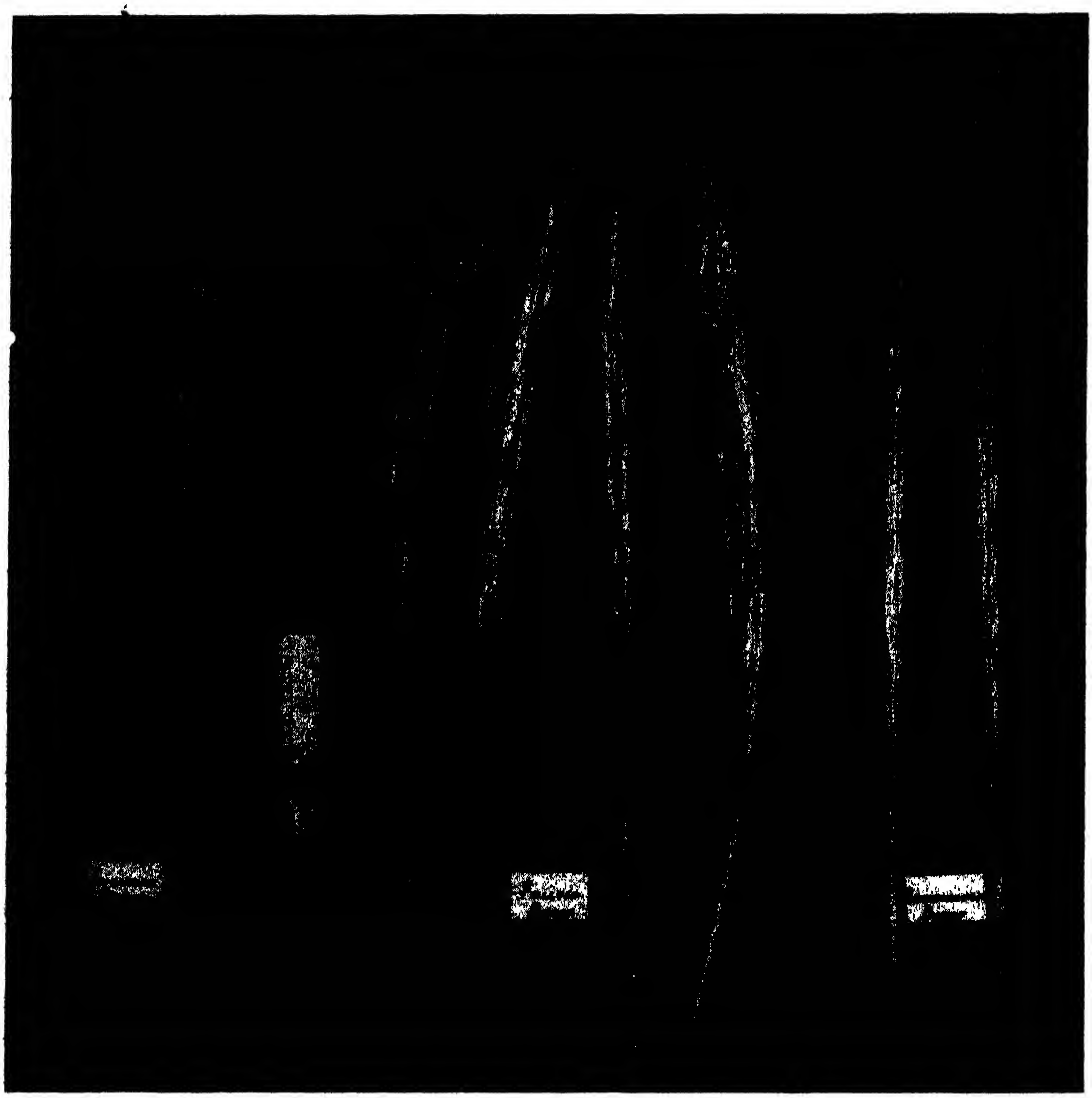


FIG. 10. Threshed and unthreshed broomcorn brush of three varieties. The European Dwarf is a common variety and the Fulltip and Scarborough Dwarf varieties are improved ones that originated in Oklahoma.

Varieties that are being produced for combine harvesting occupy the largest part of the grain-producing acreage. These varieties have been increasing in number and are extremely dwarf in stature, which results from being recessive for two genes that produce a shortening of the internodes. The list of varieties now in use includes Martin, Plainsman, Caprock, Westland, Midland, Combine kafir and the combine Sooner milos. With the exception of the Sooner milos

all the varieties named are selections from milo × kafir hybrids. The varieties are readily distinguishable agronomically. The first five varieties named have yellowish red seeds, and Martin is without awns. All these varieties have juicy stems. Combine kafir resembles Blackhull kafir but is shorter in stature. The combine Sooner milos, unlike the other varieties, are not the result of hybridization between varieties but are pure milo. One has seeds with white and the other with yellow pericarp. They are double dwarf in stature and are earlier in maturity than the other varieties. The distinguishing feature of all milos is the transverse wrinkle on the outer glume.

None of these combine varieties is more than ten years old and none is without some fault. It is likely that new varieties will soon replace those now in use.

Breeding

Much of the breeding work being done with sorghums is based on a knowledge of the inheritance of specific genes. The inheritance of genes that affect such characters as height of plant, juiciness and sweetness of stem, plant sap color, color of glumes, color of seed, type of endosperm starch and even duration of growth is known. The genetic constitution of the commonly grown sorghum varieties for many of the genes that are of economic importance is known, and it is possible to make an intelligent choice of parents with considerable assurance that a desirable strain will emerge from the cross as the result of recombination of the desired genes. It is undoubtedly true that many other characters of importance, such as resistance to diseases of several kinds, including those that produce lodging, and damage to seed in the field prior to harvest, are also genetic in nature. The sorghum species contains a wealth of variability, and much still remains to be done before most or all of the desirable characteristics have been brought together in a few strains.

An extensive sorghum-breeding program has been carried on in the United States during the past 30 years. The objectives generally have been greater yield through better adaptation, and better quality. Most of the sorghum improvement work now under way has some or all of the following objectives: more suitable maturity, more palatable seed, seed that will stand exposure with the least damage, dwarfness to make machine harvesting easier, insect resistance, disease resistance, improved forage quality, and endosperms with waxy type starch.

The mechanization of the sorghum crop that has taken place within the last ten years was possible because of the breeding work that has been done with the crop. When sorghum was introduced to this country less than 100 years ago the varieties were tall, but mutations that cause shortening of the internodes have occurred. Since grain sorghums have always been used by American farmers in large acreages, short stature was an advantage. The varieties that were commonly headed by hand in the years prior to mechanization were recessive for one gene which caused the varieties to be four or five feet tall, which is about the right height for hand heading. There is some correlation between height and the amount of lodging that occurs, and dwarfness is desirable in a variety to be combined. A second mutation that reduces internode length has occurred in sorghum, and plants that are recessive for two genes grow to a height of two to four feet. Such heights are most favorable for combine harvesting, and the efforts in recent years have been to obtain varieties of double-dwarf that are well adapted. The varieties in general use at present are all less than ten years old, and none

of them is considered to be without fault. Most of the efforts presently being made are for the purpose of improving varieties that are now being grown or to displace them with others that will be an improvement in one way or another.

One of the needs at present is to incorporate greater resistance to two fungus diseases that attack the stem and cause the plants to fall before or shortly after maturity but before the grain is dry enough to be stored without heating after combine harvesting. The presently used varieties are quite susceptible to fungus diseases that attack the grain during damp weather as the grain approaches maturity. Variations in resistance to this sort of attack exist, and one variety of Indian origin is quite resistant. Fortunately all the varieties now being used as parents as well as the commonly grown varieties are resistant to *Pythium* root rot, and the only precaution that needs to be taken is to see that susceptibility does not in some way get into the breeding stocks. Selection for resistance to this disease several years ago prevented the extinction of the important milo variety which at that time was the most important grain sorghum.

Increased resistance to insects, of which chinch bugs and grasshoppers are examples, is the objective of breeding work for particular areas where such insects frequently cause damage. In the northern part of the sorghum-producing area, the prussic acid content is sometimes high enough in sorghum forage to cause death of cattle. Selection for low prussic acid content has been effective.

There has been some breeding work done with Sudan grass, and at least three strains that contain certain genes obtained from sorgos have been distributed. Sweet Sudan grass has a distinctive glume color, is sweet and juicy, is somewhat resistant to foliage diseases, and is more palatable to cattle than the old variety. These characteristics were all transferred to Sudan grass from Leoti sorgo. Within the past three years this variety has come to occupy one-half of the acreage devoted to Sudan grass.

The manifestations of hybrid vigor in sorghum are pronounced. Much of the lateness and large size shown by some sorghum hybrids is due to the action of a few complimentary genes, but the vigorous growth and early maturity shown by corn hybrids also exist in sorghum. It is quite possible, if not probable, that the use of hybrid vigor in sorghum production will become feasible. Whenever an easy way to maintain a male-sterile stock in the homozygous condition is worked out or any easy way to bring about emasculation is devised, hybrid sorghum will quickly come into commercial use. Increases in yield as large as or larger than those obtained in corn are produced by certain sorghum hybrids. Hybrids are the easiest solution of sevseral insect and disease problems. There is every expectation that sorghum hybrids will come into widespread use whenever hybrid seed can be produced economically.

As will be seen from the foregoing discussion, most of the urgency concerning breeding work with sorghum grows out of the mechanization of the crop, but there is also another cause. Sorghum grain is just entering a period of expanding use in industry. Two of the immediate problems that must be solved are the production of varieties with waxy endosperm that are suitable for combine harvesting and are satisfactory in production, and of varieties whose seeds do not produce undesirable water-soluble pigments when attacked by diseases or insects. Since many of the problems are new, much still remains to be done before the need for new sorghum varieties is met.

It may appear that almost all breeding objectives should be possible to at-

that the drug was used by the midwives of Europe, especially in Germany. With the aroused interest in the medicinal qualities of ergot of rye, focus was first placed upon the rye as the host plant for all medicinal preparations of the drug. In 1816, however, Jacob Bigelow, a medical botanist of Boston, made reference to the fact that the rye plant is not alone a source for ergot fungus infestation. In his publication "On the Clavus, or Ergot of Rye" Dr. Bigelow mentioned that wheat plants are infected similarly and that "considerable quantities of that ergot as well as domestic rye ergot have been offered for sale at the druggists' stores". This presumably would indicate that early during the 19th century the use of other than rye ergot was made by physicians and that shortly following the aroused interest in the drug much of the domestic supply was already established.

Although the knowledge concerning ergot and its medicinal virtues has been rapidly accumulated since the early 19th century, mention should be made of the significance of ergot and ergotized host plants to the ancients and to people of intermediate time, from 500 A.D. to 1800 A.D. Accounts vary considerably and are limited in regard to the early medicinal importance of ergotized grains. Schelenz and Achundow (1) reported that ergotized grains were used by the Chinese midwifery at an early date. Mention is made of its use similarly by Arabian medicine. There are evidences among the records of the Moorish physician, Avicenna, which indicate that the fungus was used medicinally during the 10th century.

The greatest historical significance of ergot and ergotized grains up to the 20th century has been the disease ergotism accompanying ergot-infected foods. This disease proved to be fatal to thousands during the endemic and pandemic plagues of Europe and Russia during the 10th, 11th and 12th centuries when the peasant class ingested ergotized grains. The disease was characterized by a gangrene development in the limbs of the victim due to the severe vasoconstriction and pressor actions of the ergot alkaloids. Such an action would eventually result in a numbness of the appendages, shrinkage and finally separation and dropping off. According to the description in the "Annales Xantenses" of 857 A.D., "a great plague of swollen blisters consumed the people by a loathsome rot, so that their limbs were loosened and fell off before death". The great ergot plagues of the middle ages, which were known as "Holy Fire", "St. Anthony's Fire", "St. Martial's Fire", the "ignius Beatae Virginis invisibilis or infernalis", were all associated with ergotized grains of the rye. Wahlin (2), who reported in 1765 on similar epidemics in the provinces of Jonkoping, Westergotland, Kronoberg, and Carlskrona, Sweden, has attributed the cause of the disease in these areas to ergotized barley and oats.

Kobert in 1889 made a study of the use of ergot among Greek and Roman times. He found substantial evidence for the fact that a true ergotism did exist among populations during the periods of Hippocrates, Dioscorides and Galen. This is interesting because of the general belief that rye plants were not commonly grown by the ancient Greeks and Romans. If this disease were true ergotism and not the result of the similar physiological action caused by eating corn darnel, black wheat or other smuts and rusts, it would indicate that ergot from cereals other than rye, perhaps fodder grasses, were of significance during Greek and Roman times.

Among the latest reports of ergotism from the ingestion of contaminated cereal grains are those concerning an outbreak of the disease in the States of New York, Ohio, Iowa and Kansas from

1820 to 1885. There was a similar outbreak as recently as 1926 and 1927 in the Ukraine region of Russia. These epidemics were from ergotized rye, wheat and oat grains. A small outbreak of ergotism occurred in Belgium during 1844 and was localized in Brussels. This was attributed to ergotized oats and rye.

Development of the Fungus

Botanists are well aware of the large number of grasses which are attacked by parasitic fungi. Many of these parasitized plants are susceptible to infections produced by species of the Ascomycete genus, *Claviceps*. The most common species of the genus is *Claviceps purpurea* (Fries) Tulasne. In 1822 the research of Fries, and later that of Tulasne (1852), made clear the nature of the life history of *Claviceps* development in infected grain ovaries. These workers divided the life cycle of the fungus into three phases in which the initial phase was termed the "sphacelium" stage or that form of fungus which attacks the delicate ovary of grasses; the second phase became the "sclerotium" stage or that stage which represents the resting period and which is characterized by a compact hard stroma or mass of mycelial tissue; and, third, the sexual fructification stage during which there arise also asexual fruiting bodies. The latter structures bear conceptacles, sporangia and spores.

The host plant, presumably always a member of the grass family, is attacked according to a consistent method of asexual spore dissemination. This takes place whenever parasitic *Claviceps* species in the form of ascospores or conidiospores (conidia) are present in sufficient numbers in fields of grain. Such is the rule during damp warm weather. By the agency of insects or wind these spores are scattered to young ovaries of a grain plant. The spores are lodged either singly or in clusters about the base of the grass ovary, and in the presence of moisture they soon begin to germinate. The first visible sign of germination is the presence of characteristic multiseptated hyphal filaments which appear to penetrate and spread over the basal portion of the ovary. These hyphal filaments branch profusely to form a dense fungous growth, the mycelium, which superficially covers the ovary. While the mycelium twists and branches over the ovarian tissues, fermenting substances, which are secreted by it, cause gradual decomposition of the entire ovary. The resulting mucous-like substance, called "honey dew", forms a spongy mass over the upper end of the ovary. In the meantime the modified ovarian structure increases in size. Close examination of the upper extremity of this structure reveals chains of asexual unicellular conidiospores in great numbers. These become abstricted and fall to the ground or are dispersed by means of insects. Such spores have been shown to retain viability for several years.

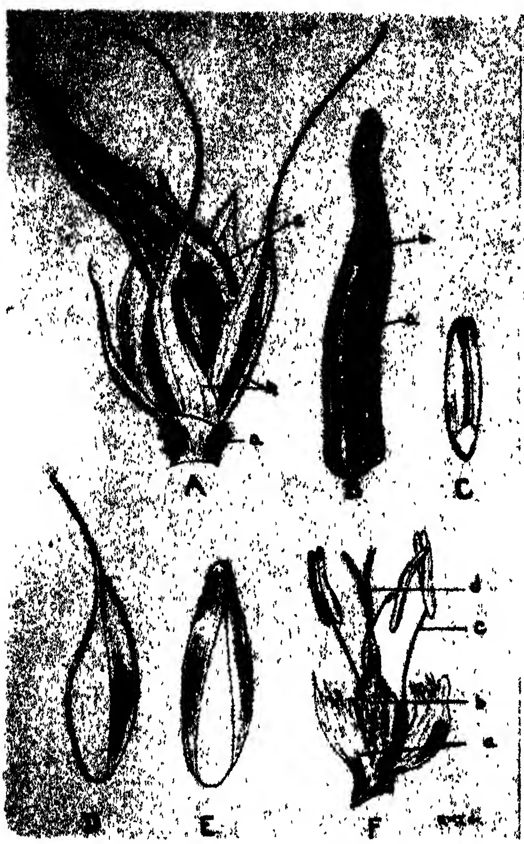
The release of conidiospores by the developing ergot ends what is called the "sphacelial phase" of the life-history. With penetration of the threads of mycelium deeper into the ovary of the grain a mass of fungal growth soon fills the space of the entire ovary. Microscopic examination of the ovary at this time reveals only a hardened compact mass of fungal tissue. Such a mass assumes a somewhat curved form and becomes the resting stage or sclerotium of the fungus. It is this purplish-black to brown hardened form which becomes the crude drug of commerce or the destructive form of ergot disease which is the menace to the grain grower.

The ergot sclerotium tends to dry somewhat within the spikelet of the grain and may remain there until the period of threshing, or may soon fall to

the ground. In any event, should it lodge on the ground, it will either develop fruiting stalks at once or remain dormant over winter and then sprout during the spring. The fruiting sprouts are characterized by the presence of many long-stalked globular heads (fruiting heads), each of which is called an "ascocarp" or "stroma". Within each grains are quickly infected, and the fungus soon spreads over a wide area to ravage a grain field. If collected, however, these become the source for several medicinally important alkaloids.

Species of Claviceps

By means of artificially germinating the sclerotium stage of *Claviceps* spp. or



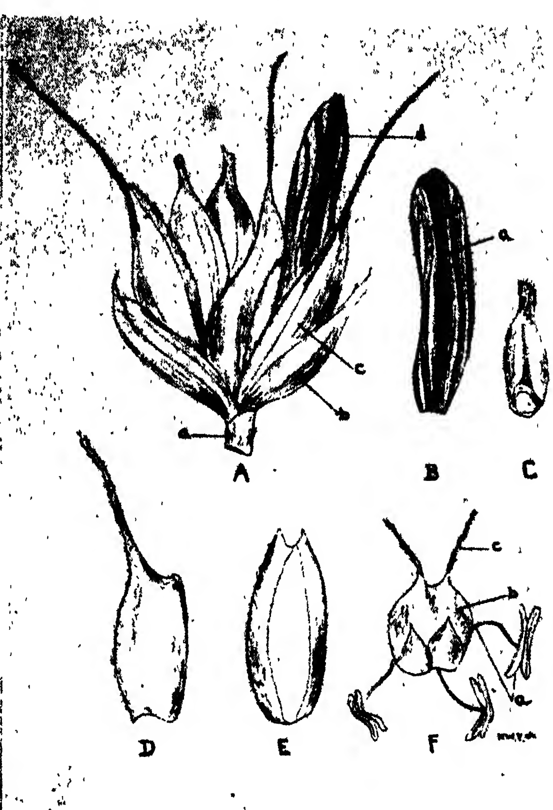


FIG. 1 (*Left*). Ergot developing in spikelet of domestic rye, *Secale cereale*. A, spikelet: a, rachilla; b, glumes; c, ergot sclerotium; B, ergot sclerotium: a, longitudinal furrow; b, transverse fissure; C, rye caryopsis; D, glume; E, lemma; F, flower: a, lodicules; b, ovary; c, stamen; d, style.

FIG. 2 (*Right*). Ergot developing in spikelet of domestic durum wheat, *Triticum durum*. A, spikelet: a, rachilla; b, c, glumes; d, ergot sclerotium; B, ergot sclortium: a, longitudinal furrow; C, wheat caryopsis; D, glume; E, lemma; F, flower: a, stamen; b, ovary; c, style and stigma.

ascocarp are flask-shaped cavities, the perithecia, each of which bears cup-shaped sacs or asci, each of which, in turn, encloses six to eight unicellular ascospores. After distintegration or rupture of the ascocarps, neighboring by inoculation experiments, species of the genus have been studied for variations. It appears evident through the research of Barger (3) that, in general, each species is limited in development to a particular kind of host plant. For

example, *Claviceps nigricans* has been found restricted in development to plants of the Cyperaceae. Further, Reed and Vavilov (4) have shown that parasitic fungi inhabiting a number of host plants may be structurally alike, but that when transferred from one species of host to another no development will ensue. The assumption is often made that the spores of a particular race of *Claviceps* species can infect host plants susceptible only to that race. Stager (3) has shown that infection by *Claviceps* species may never proceed beyond the sphacelial stage in some grain ovaries by inoculation methods on *Melica uniflora* and *M. mutans* and later transferred to *Sesleria coerulea.* The latter grass appears to be immune to *C. purpurea* infestations.

Sources of Domestic Ergot

Since the acceptance into official medicine of ergot and its several important active alkaloidal constituents, such as ergotoxine, ergonovine, ergotamine and ergotinine, more interest has been created in the cultivation and use of the domestic supply of the crude drug. This has been especially so during shortages

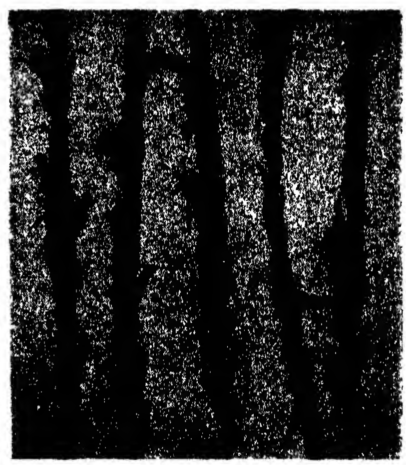


FIG. 3 (*Left*). Ergot developing on domestic rye, from fields of Minnesota.
FIG. 4 (*Right*). Ergot developing on domestic quack grass, *Agropyron repens.*

to form ergot sclerotia. Of the species of *Claviceps, C. purpurea* appears to be the most fertile. Some 16 grasses, including wheat, rye, barley and species of *Festuca, Bromus* and *Poa,* as well as some of their hybrids, have been used with success as host plants during racial studies of sclerotia development in this species.

Among other economically important species of *Claviceps,* there are races of *C. microcephalia* which is an abundant infestor of the common reed, *Phragmites communis,* and of *Aira* spp., *Poa annua* and *Nardus stricta;* and races of *C. sesleriae* which were artificially produced

of foreign supplies. Historical accounts of the ergotism plagues have shown that European rye plants are not the only sources of a potentially potent Ergot, but that domestic grasses and sedges of additional types will act as hosts to potentially active ergots. Consequently, ergots growing on a number of domestic grasses and sedges have been investigated medicinally and physiologically. Many of these investigations have also been stimulated because of ethno-botanical findings. It has been shown as the result of such studies that sclerotia of the fungus *Claviceps,* no matter what the host plant may be, have medici-

nal properties, such as vasoconstriction and muscle stimulation, which agree in character although not always in intensity of action. Among those domestic plants which harbor sclerotia most comparable to European rye ergot are *Agropyron repens*, *Glyceria nervata*, *Elymus virginicus*, *E. condensatus*, *Avena sativa*, *Zea mays*, *Palniae* spp., *Phleum pratense*, *Zizania aquatica*, *Ampelodesmos tenox*, *Triticum sativum*, *T. repens*, *T. durum*, *Lolium* spp. *Psamma* spp., *Dactylis* spp. and *Anthoxanthum* spp.

Barger (3) has listed the following number of known host plants for the ergot fungus; among the Gramineae, 66 genera including over 250 species; among the Cyperaceae, four genera, each with about ten species; among the Juncaceae, one species, *Juncus glaucus* Sibth.

Domestic Ergot compared with Foreign Ergot

In a study to compare commercial crude drug grades of domestic ergot with those of foreign importation into the United States, Youngken *et al.* (5) have shown that ergots from domestic rye, wheat and a wheat hybrid, *Triticum durum* Desf. crossed with *Elymus condensatus* Presl., compared very closely in structural and phytochemical characteristics with those from several European rye sources. Sclerotia of domestic and foreign rye ergots are generally larger in size than those of wheat ergot. Most domestic wheat ergots have conspicuously blunt extremities as compared with the tapering-to-pointed ends typical for rye ergots of both foreign and domestic sources. Rye ergots generally are larger in length and thickness than those of wheat, oat and rice. The pseudoparenchyma cells of domestic wheat ergots differ somewhat in being more compactly arranged than those of rye ergots. It is difficult to distinguish between these sources when powdered drug material is to be examined. Some domestic wheat ergots appear in drug markets with a striated marked outer rind. These are colored purplish-black with various tints of rose and have a smoother waxy surface than sclerotia of other wheat, rye and oat ergots. These striated varieties appear to develop in large quantities in fields of the domestic wheat, *Triticum durum*.

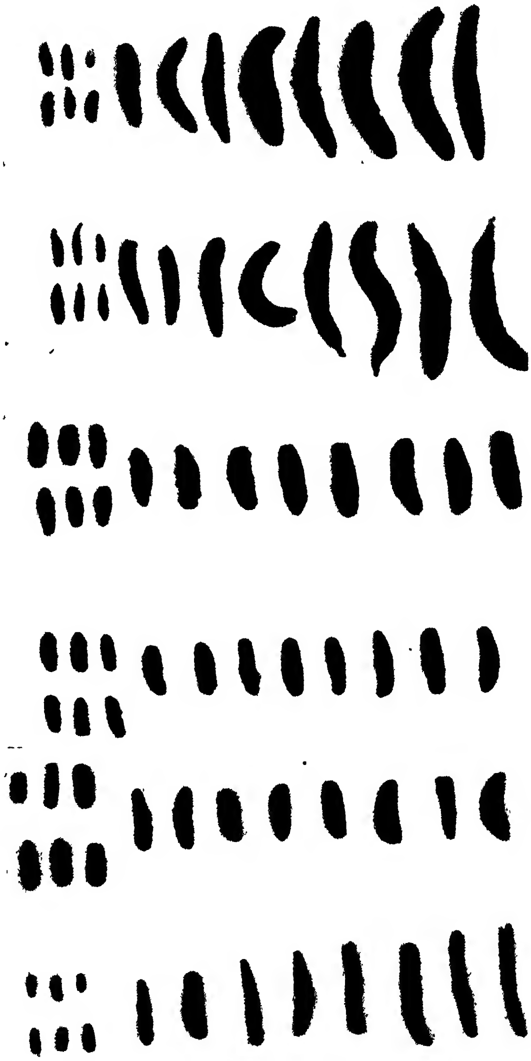


FIG. 5. Ergot from various sources, reading from top down: Spanish rye; Minnesota rye; Minnesota wheat; Minnesota durum wheat; "striated" ergot, domestic durum wheat; domestic hybrid, *Triticum durum* × *Elymus condensatus*.

There appears to be little or no striking differences in comparative results obtained from microchemical coloration tests, fixed oil determinations and moisture content for ergot of domestic rye or wheat sources when compared with good grades of European and Asiatic ergots. On the other hand, because of the poor conditions under which much foreign ergot is imported, it has frequently been observed that foreign drug is inferior to domestic ergot in morphological appearances and total yield of dried at a temperature not to exceed 40° C. Ergot which has been exposed to excessive moisture, more than 6% or 7%, will develop a brown-to-purple internal color instead of retaining its normay gray-to-white color. It will also possess a musty or rancid odor.

Physiological Reports on Domestic Ergots

There is a meagre amount of data available on the studies that have been conducted on the physiological activity of

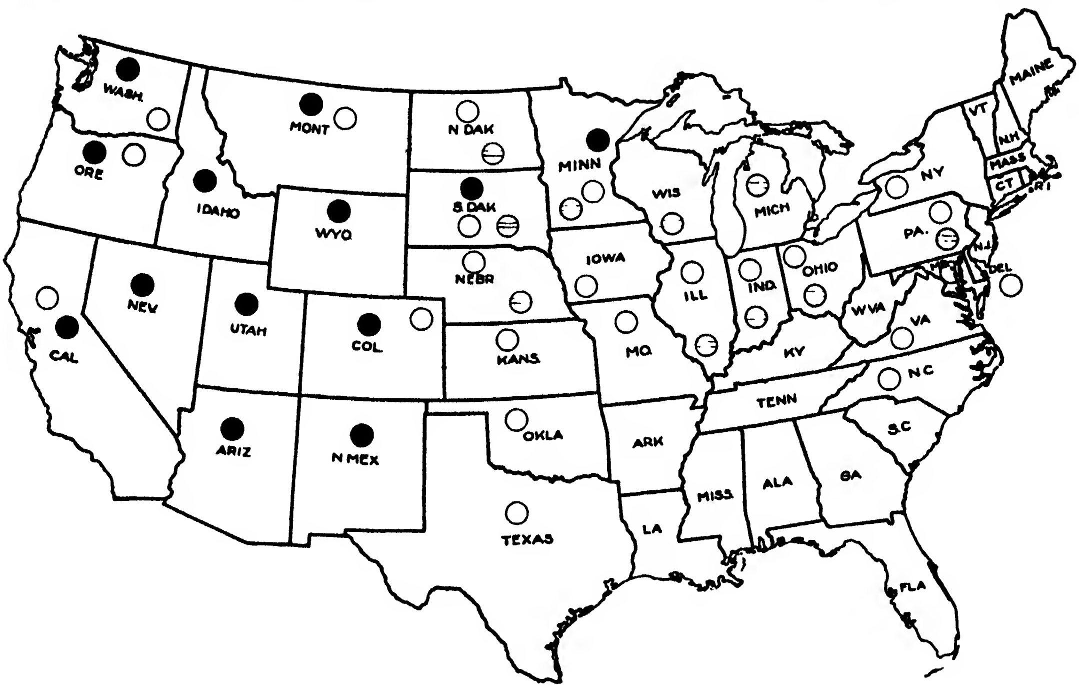


FIG. 6. Principal States producing rye, *Secale cereale* (lined circle); wheat, *Triticum aestivum* (open circle); and domestic giant wild rye, *Elymus condensatus* (black circle).

active constituents. The usual report is that the alkaloidal content of most sources of domestic ergots of rye are found to be greater than comparative imported sources. On the other hand, good quality ergot from domestic wheat supplies has been found to be lower in total alkaloid content than that of rye sources.

Storage and drying conditions for ergot of any source must be carefully observed. The drug should be stored in moisture-proof containers and should be ergots obtained only from domestic sources. The fact that the domestic supply has never reached the proportion of the imported supply has probably been responsible for manufacturers of ergot preparations to rely upon foreign shipments. This has been true as long as the latter have measured up to Pharmacopoeial specifications. Newcomb and Brown (6) and others have shown that domestic grown ergots compare favorably in physiological activity with selected samples of Spanish and Russian ergot.

In many cases they attach more value to domestic rye samples studied than to those of the foreign source. Munch (7) found that ergots obtained from quack grass, *Agropyron repens,* and from wheat, *Triticum aestivum,* both from fields in South Dakota, North Dakota and Minnesota, were from one to three times as potent in physiological activity as is required, according to minimum requirements for ergot of rye of United States Pharmacopoeia standards (U.S.P. X). Several samples of ergot obtained from rice, *Oriza sativa,* grown in Minnesota and assayed according to the U.S.P. XI cock's comb method, were found to be physiologically active and of good potency.

Denniston (8) has described the character of several ergot grains from wild rice, *Zizania aquatica* L., used by the Indians of northern Wisconsin predominantly in midwifery. Brown and Rauck (9) reported that the cause of several abortions among cattle in Mississippi and the Mississippi River Valley was due to the physiological activity produced by ergot of *Claviceps paspali* found infecting *Paspalum* species. There are reports of abortions among cattle grazing in ergot-infected rye, wheat, barley and other grasses of the West and Midwest.

The physiological activity of many ergots, in addition to the rye source, that are available within the United States, is attractive and warrants further investigation.

Economic Status of Ergot

Despite the indications of physiological activity produced by ergots of other than rye plants, the latter remain the chief ergot of clinical and manufacturing use. It is important that, due to the larger size of the rye ergot, this ergot is easier to separate from the grain, and such a factor influences its commercial availability.

Since the close of World War II the economic situation relative to the market in all botanical drugs has been improving and slowly returning to prewar levels. According to Industry Report (10) of the Department of Commerce and several of the trade news, many foreign suppliers of ergot of rye are returning to the markets. For example, during January and February of 1945 over 44,000 pounds of ergot of rye were imported. During the same months in 1946 about 42,000 pounds were obtained from abroad. In the shortage periods beginning in 1941 most American users of ergot were relying upon isolated spotty collections of the drug made by several crude botanical dealers within the United States. Wheat ergots as well as rye ergots were used by pharmaceutical manufacturers whenever large enough collections could be obtained. As much as three and four dollars per pound were paid for domestic drug. As a result of this, isolated areas of the wheat- and rye-producing States of the Midwest and South became important sources for the supply. Much domestic rye ergot has entered botanical markets from Minnesota, Wisconsin and the Dakotas. Other important sources are Illinois, Indiana and Nebraska. It has been estimated by the Bureau of Foreign and Domestic Commerce of the Department of Commerce (11) that during 1941 the United States produced about 100,000 pounds of ergot of rye, Spain supplied this country with 400,000 pounds, Russia 300,000 pounds, Portugal 150,000 pounds and Germany 100,000 pounds, and that from all other countries this country imported about 150,000 pounds.

It is evident that, although much ergot fungus develops annually in the wheat and rye fields of the country, relatively little of this domestic supply actually enters the drug markets during normal times. Due to the fact that only the rye source is acceptable for use as the official Pharmacopoeial drug, very little

wheat ergot is used commercially in pharmaceutical preparations. But even in cases of the rye ergot farmers prefer to burn the fungus rather than to compete with the foreign market or to run the risk of ergot-ravaged grain crops. Recent actions taken by the Federal Drug Administration in detaining many arrivals of ergot shipments from abroad because of poor quality drug has encouraged some grain growers to continue dealing with domestic outlets.

The collection of ergot is almost entirely a peasant industry abroad where it is usually picked by hand. Its domestic development or even that in foreign countries varies according to rainy seasons, heat and humidity. If not eradicated as a dangerous crop fungus growth, its collection varies from season to season. In the United States the fungus is separated by special machinery in terminal elevators which clean the ergot out of the rye and wheat. Some elevators retain the ergot screenings for sale, depending upon prices offered. Others destroy the screenings.

While dealers in crude ergot and manufacturers who use the drug replenished depleted stocks during the latter part of the war and into 1946, the price level remained between $1.65 and $3.00 per pound. In April, 1947, the price level reached to between $1.25 and $1.50 per pound. Even during normal times these price levels fluctuate, depending upon the rye crop prospects. For example, during 1931 and to 1934 the price range was between 32 cents and 47 cents per pound. From 1936 to 1940 the price ranged from a low of $1.25 to $3.85 per pound.

Conclusions

Despite the evidence of the physiological potency of ergot from other sources than the rye plant, the official standards do not permit those of wheat, oat, barley and rice to be marketed as United States Pharmacopoeial or National Formulary products. This restriction determines the foreign and domestic supply of the drug. Reports indicate that there is far more domestic wheat ergot developed in this country than domestic rye ergot. Considering the fact that prior to the past war more than 30 million bushels of rye were produced in a year in ten leading rye-producing States and that more than 490 million bushels of wheat were produced in the same year (1939) in ten leading wheat-producing States, potentially the wheat ergot and rye ergot yield should be great enough to become an important domestic source of drug.

It appears timely, therefore, that investigations be undertaken to develop the two foremost ergot supplies of the United States—rye and wheat ergot. Such an investigation might result in the use of wheat ergots in official medicines as well as that of the rye. This, it would seem, could be done under careful supervision so that there would be no fear of ravaged grain crops and the dreaded disease, ergotism.

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The Culture of Cork Oak in Spain

Where over-intensive use of the forests may be leading to the loss of a centuries-old plant-utilizing industry.

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Introduction

CORK is such a common, yet unobtrusive, material that we usually take it for granted with never a question as to its picturesque source or colorful history. While most of the common trees and shrubs, and even the herbs, produce some cork, only a half dozen species of plants produce enough to be of potential economic importance. The "corkwood" of commerce[3, 4] from which cork products are made, is the outer bark of the cork oak (*Quercus Suber* L. and its varieties), a large evergreen oak that once girdled the Mediterranean but now is limited to the lands bordering the western half of that sea. A peculiarity that adds greatly to the value of cork oak is its ability to regenerate in a few years the corky outer bark after it has been peeled off or "stripped."

Cork has been, throughout historic time, one of the important agricultural products of Spain. It is closely linked with that most famous of Spanish industries, wine production, as well as being in its own right a major export product. Good husbandry has preserved the cork forests despite increasing economic pressures that might lead to their destruction, in the same way that many American forests were destroyed—by over-intensive use. The visitor with a knowledge of the history of forestry in the United States finds himself unconsciously watching for signs and for trends that will help him to estimate the status of the cork industry, to judge whether all is well or whether Spain, like

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[1] It was the writer's privilege, in the winter of 1943–44, to study cork production in Spain under the joint auspices of the U. S. Forest Service and the Crown Cork and Seal Co.,[2] of Baltimore. The comments and opinions expressed here are the result of actual observation and discussions with Spanish officials and business men interested in cork. The reader should bear in mind, however, that when judgments of so ramified a subject as the cork industry are based on only three months of observation, many mistakes are possible. Any misinterpretations of fact must be charged to the author—not to the hospitable Spaniards who did so much to make the assignment both pleasant and profitable.

On arriving in Lisbon, Mr. Melchor Marsa and Señor E. Mas were awaiting me, and three months later, on my return from Spain, Sr. Mas was again my generous host. Among the many Spanish officials and business men who unstintingly gave of their time and resources that I might have a better understanding of Spain and the cork industry were Señores E. Morales y Fraile, Salvador Robles Trueba, Luis Ceballos Fernandez, and El Marques de Villa-Alcazar, all of Madrid; Sr. Bonal of San Feliu de Guixols; Sr. Domingo Serra and Sr. Haya of Sevilla. Special acknowledgment is due Sr. Rogelio Mont Maruny of Sevilla who throughout my stay in Spain was my mentor, guide, business agent, host and loyal friend.

[2] See page 445 of this issue, and page 316 of Vol. 1 No. 3 of ECONOMIC BOTANY for abstracts concerning the cork oak-planting activities of the Crown Cork and Seal Co. [Ed.].

[3] Small amounts of cork are harvested from the "Pau Santo" (*Kielmeyera coriacea* Mart.) tree of Brazil for use in Rio de Janeiro and Buenos Aires. In Japan a small amount of cork is harvested from a native species of oak (*Quercus variabilis*) and used locally.

[4] The reader's attention is directed to the article on "The Cork Oak Tree in California" in Vol. 1 No. 1 of ECONOMIC BOTANY [Ed.].

the United States, is faced with shrinking forest resources.

Cork has several inherent characteristics that make it valuable to man. It is light in weight, buoyant, resilient, has a high coefficient of friction, is chemically inert, practically waterproof, tasteless, odorless, soft and warm to the touch and has pleasing texture and color. These qualities make it suitable for many things such as floats, stoppers, grips and handles, insulation and flooring. Substitutes for cork are plentiful in many fields of application. On the other hand, new uses are being found and old uses are being expanded so rapidly that the world production of some 300,000 long tons yearly is readily absorbed by an eager market of rising price.

History

When man first made use of cork is not known. Theophrastus, in 288 B.C., described cork as a product of the Pyrenees. Other early writers also mentioned cork and its qualities, indicating that long before the time of Christ, fishermen used it for net floats, vintners used it with pitch to seal wine jars, while Iberian peasants often roofed and floored their huts with cork slabs to insulate them from heat, cold and moisture. Today these same uses—floats for various purposes, stoppers and closures for fluids, and insulation—require the greater portion of the annual cork crop. One may even find occasional peasant huts in Spain that are roofed with cork slabs from the forest.

In the seventeenth century, with the development in Germany of the glass bottle, came the industrialization of cork. The craft of cork cutting emerged. Three quaint little seaside villages—Palamos, San Feliu de Guixols, Llagostera—in the north Spanish province of Gerona because the early centers of cork manufacture. Nimble fingered workers with keen-edged knives sat at their sidewalk benches and cut to order stoppers for wine bottles—as many as 2,500 per day by a skilled worker. German money and markets were largely responsible for the early development of the cork industry, but the shrewd energetic Catalans of north Spain became the factory managers, the technicians and the skilled labor of the industry. To this day a goodly portion of the directive and supervisory talent of the cork industry throughout the world is supplied by Spaniards, Catalans in particular.

Supply and Present Production in Spain

Of the 2,000,000 acres in Spain where cork grows naturally, only 840,000 acres are in commercial production today because of the thin stand of trees in the drier localities, the preponderance of other tree species than cork oak in many forests, or other factors that make commercial production unprofitable. The greater gross production of corkwood is in southern Spain, although northern cork is often said to be of better quality. The cultural practices of the two sections differ in detail due to differences in land ownership, land management and use, and the customs of the people. In north Spain the forest holdings of individuals are in smaller acreages, often consisting of woodlots adjacent to the small farms. In south Spain, on the other hand, are located tremendous estates that have been handed down within certain families for generations.

In the mountains and broken terrain, both in the north and in the south, dense forests may be seen. These are mostly of mixed oaks and other hardwood species. Cork oak may be scattered thinly among other kinds of trees, or in places it may comprise almost all of the stand. In the rolling hills and dry tablelands, particularly of south Spain, the forest consists of widely scattered hardwoods, often presenting the appearance of a

FIG. 1. (*Upper*). Old cork oaks along the road between Algeciras and Tarifa, Spain. The cement slabs along the road represent only safety precautionary measures.

FIG. 2. (*Lower*). Stacks of cork near Algeciras, Spain, awaiting shipment. (*Photos courtesy Crown Cork & Seal Co., Baltimore, Md.*)

sparsely wooded grassland. Here again the cork oak may comprise a large or a small part of the tree stand, depending on local conditions.

Always the cork oak is picturesque, with great gnarled branches and a wide spreading crown resembling the live oak of the southern United States. The trunks of some are smooth and cinnamon brown—young trees stripped of their corkwood for the first time within the year. Others show the scars and calluses of a hundred years of periodic stripping. In parts of the cork-producing country, particularly where the land is level or rolling, there is at times little reproduction of young trees. The visitor often has a disquieting premonition that the forest giants will one day be gone—with nothing to replace them. Yet the very presence of the forest, after three hundred years of intensive use, reassuringly demonstrates the value placed on conservation by the Spaniard.

Operations

Normal practice throughout the Mediterranean region is to strip the cork from trees more than eight inches in diameter in July, August and September. The Spaniard prefers for this operation a nicely balanced, short-handled, light weight broad-axe, centuries old in design. In some localities he chops a series of holes through the outer bark and uses them as a ladder to climb to the desired height. He then deftly hacks and peels the bark from the trunk in great slabs, often six feet long and half as wide, as he descends. A skilful workman strips about 1,200 pounds of cork per day. In North Africa and Portugal, ladders and saws are frequently used, but the fundamental process is essentially the same.

The time interval between strippings of the same tree is from 9 to 11 years, depending on the growth rate of the trees in the region in question. The forest owner seldom strips all trees the same year. He finds it more profitable to arrange the stripping of a part of his holdings each year. Corkwood is said to strip best after a rain, but as summer rains are very uncertain the harvest is planned without regard to the weather.

Local custom determines the method of disposing of the corkwood. After being stripped from the trees it may be piled near where it is stripped or it may be shipped by cart or wagon direct to the factory. More commonly, however, it is hauled to central concentration points in the forest where the cork of several owners may be assembled. Buyers examine the cork piles of the various owners before the auction, if one is to be held, so that they may bid intelligently on the various lots offered. One interesting variation of the auction is used extensively in north Africa and to a less extent in south Spain. The auctioneer first asks a price above what he expects to get. He then drops the price rapidly step by step until someone bids. The first bidder takes the lot being offered. The bidder must be shrewd and alert to secure for his company the quantity of cork desired at a favorable price. My respect for the cork buyers increased tremendously on closer acquaintance. In addition to the Spanish dialects, units of weight and money, the cork buyer for a large firm must be familiar with customs, money and languages of south France, Portugal and north Africa.

After the manufacturer has the cork in his possession it is graded very carefully into as many as 20 classes in some factories, depending on its fitness for various purposes. Cork grades are based on the size and thickness of the slabs; the presence of cracks, breaks and fissures in the "belly" or the "back" of the slab; the presence of pits, holes and injury or granular inclusions in the cork; the texture, density, color, presence of stains, uniformity, *etc.* of the material. The cork grader requires a

Fig. 3. Cork being stripped in one continuous piece 15 or more feet tall from the trunk of an old cork oak in Spain. (*Courtesy Crown Cork & Seal Co., Baltimore, Md.*)

keen eye, sensitive touch, thorough knowledge of grades and the uses to which they are put, and sound judgment; qualities that require years of experience to develop. Because of the small margin of profit on which cork is manufactured, improper grading could and sometimes does mean the difference between profit and loss to the factory.

Highest quality cork is made into stoppers for the sparkling wines such as champagne—in fact, the supreme test for cork quality seems to be whether it is suitable for champagne stoppers. Other grades of cork are used for stoppers for various sizes of bottles, for shoe insoles, crown cap liners, fish net floats, *etc.* The scrap left from cutting these products together with the low-grade cork is ground and used as hot pressed blocks for insulation, or for composition cork, the particles of which are cemented together. Cut cork products are still made chiefly in Europe, while the United States has become the leader in the production of ground cork products.

In the cork factories of Spain are seen all degrees of mechanization and working conditions. Shoe insoles are most often cut by hand, with the aid of a metal pattern and sharp knife, from sheets of cork that have been sliced by machine. Hand cut champagne corks are often preferred by the vintners. These are square in section with rounded corners, the belief being that this shape makes a more efficient seal than the round stopper. Small bottle corks are most often run through a punch machine by hand. It has been learned that a careful machine operator can cut more usable items from a single slab when feeding the machine by hand than can be cut by a fully automatic machine because of irregularities in size and shape of the slabs and the irregular distribution of imperfections in the cork. The trend, however, at the present time, is toward more automatic machines and more mechanization throughout the industry, because of the rising cost of labor in proportion to the value of the material wasted by machine cutting.

Working conditions in the Spanish cork factories are not comparable to those in the United States because of the entirely different social and economic system. During the winter the writer spent in Spain there was an acute shortage of electric power for light and heat and operation of machines due to drought and consequent low water storage. Cork factories in Sevilla operated only three days per week during part of the winter, with strict limitation of light and heat. The lack of heat was no great hardship, however, as there was no frost, and the midday temperatures were comparable to those of southern California or Arizona.

Economics

The visitor to Spain, if a botanist or a forester, is prone to speculate on future developments of the cork industry by what he sees today. Wherever he goes he sees evidence, bits of a pattern, that when fitted together form his picture of cork production as it is and as it seems likely to develop if present trends continue. There are several forces, rooted deep in custom, tradition and economic practice, that operate slowly but certainly to diminish the potential amount of cork that Spain can produce. To give an understanding of the complex situation these factors and those that counterbalance them must be examined. Some of the factors have been operative through two centuries or more, always tending to reduce not only the total acreage of cork forests but also the percent of cork oak in relation to other species. Among these factors are livestock husbandry, the use of cork oak for fuel, stripping injuries, cropping the land between trees, and subjugation of land for farming.

Grazing and foraging of forest land by

hogs, and to a less extent by other livestock, is an important and age-old business of Spain, in common with other western Mediterranean countries. It is the opinion of many forest landowners that over a period of years fees for allowing hogs to harvest the acorns will yield a greater and more dependable income than that from other forest sources. Light winter grazing by hogs and goats is believed to be beneficial to the forest, as many acorns are tramped into the ground where they sprout and grow. Heavy grazing by hogs or by goats has a bad effect at any time, particularly in a moist early spring when young trees may be chewed off, trampled or uprooted. Other classes of livestock, too, are capable of doing great damage to young trees and preventing reproduction of cork oak, but because they are fewer in number their damage is less.

The cork oak acorn, called the bitter acorn, is an excellent feed for livestock, and is sometimes eaten by the peasants during times of stress. On the other hand, the acorn of the holly oak, called the sweet acorn, is considered an even better feed. In addition, the holly oak bears a larger acorn crop per tree, and bears more regularly year by year than the cork oak. For these reasons the forest owner may sometimes favor reproduction of the holly oak rather than the cork oak because of its greater value as a producer of hog feed.

Cork oak, as well as other Spanish oaks, is excellent fuel and makes good charcoal, a vital and valuable product in Spain. Normally prunings, thinnings, and trees past the age of usefulness are converted into charcoal. At times the owner under economic pressure may convert many young, vigorous cork oaks into charcoal at the expense of future cork production.

Stripping also results in some loss. A loss of three to five percent of the trees is expected at the first stripping. After the first stripping the rate of loss drops sharply, but there are occasional losses of older trees, particularly when they are stripped severely, that is, when an unusually large area of bark is removed. Stripping also results in considerable accidental injury when the workman's axe may slip, or he may make his cut too deep. These injuries cause callus tissue knots to form, and in time, after many strippings, the cork oak trunk may become as warty as a cucumber. The quality of the corkwood produced by such trees is low, and they are often removed, the wood being converted into charcoal, the cork being stripped from even the smaller branches, and the inner bark being sold for leather tanning.

It is the practice in parts of Spain to plant crops between the scattered cork and holly oak trees during years when there is ample winter rainfall. Such cultivation, although not of outstanding importance, may, where it is practiced as often as once in five or six years, prevent the reproduction of young trees.

All of these practices and customs affect the long range outlook for cork production. The fluctuation of market prices sets the various trains of events in motion. During periods of high corkwood prices, trees are often severely stripped. Heavy tree losses and much trunk injury may result, particularly if the stripping season is followed by an unusually cold or dry winter.

During years of light demand and low corkwood prices, in order to produce necessary income, the forest owner may be forced to cut many trees for the production of charcoal, fuelwood and tanbark. A rise in price of any of these products may be reflected in heavier cutting of forest trees.

Likewise, when pork products are at a premium the forest may suffer. To take advantage of a favorable market, or of the relatively cheap feed, large numbers of hogs may be fattened in the

forest. Swineherders take half grown animals into the forests in late autumn. By spring the hogs are fat, having fed on acorns for five or six months: those from the deciduous oak in the autumn, from the cork oak in midwinter, and from the holly oak in late winter and spring. Much damage to young trees can result from this program unless great care and good judgment are exercised.

The Future of Cork in Spain

We have now examined at some length the factors that have slowly been depleting the cork-producing forests of Spain. In contrast to these let us examine some of the factors that have helped conserve the forest resources for three hundred years, or that give promise of helping in the future. In the first place it has long been the custom, so it is said, to periodically protect the forest from grazing or to allow only light grazing for a series of from five to ten consecutive years. If this is done once in fifty years the forest can be maintained. Then there has been in recent years an increasing interest in government acquisition and redistribution of large forest holdings and in the development and introduction of better forest practices. The chief of the Spanish Forest Service, Sr. Salvador Robles, is an able, well trained forester, who sees the problems clearly and who is advocating a sound and progressive program of education and control that makes the future encouraging. The effects of this program will be increased per acre cork yield, increased reproduction of young trees and less damage to trees during grazing and stripping operations.

Another greatly needed development that would, perhaps, protect the future supply of cork even more than regulation of the forest is the construction of large storage dams for hydroelectric power and irrigation. The potential waterpower that could be developed is great. Spanish engineers and agriculturists are looking in this direction. Power for factories and for city homes would greatly reduce the need for charcoal in this land without oil and with little coal. Water for irrigation would increase the supply of food and feed. The general effect would be to raise the economic status of much of Spain's population, and in so doing, to reduce the pressure for over-intensive use of the forest.

It will be interesting to watch the course of future development in Spain to see whether the colorful and historic cork industry continues to grow, or whether it is gradually crowded out by other industries that may prove to be of greater economic value, or whether the cork forests, as with some American forests, are destroyed by over-intensive use.

Utilization Abstracts

Sunflower Seed. In 1946, 25,000,000 acres of sunflowers were grown in the neighborhood of Altona, Manitoba, Canada, by the Mennonite farmers of that region. The crop was raised for production of sunflower oil which, since sunflower growing was started there three years ago, has found increasing use for household purposes, pharmaceuticals and shortening. The residual oil-meal cake, after the oil is pressed out, and the hulls are used by feed-mixing concerns. (*Agricultural and Industrial Progress in Canada*, as reported in *Chemurgic Digest 6(8): 151. 1947*).

Edible Nuts of the Pacific Northwest

Only four kinds of native nut—hazelnut, chinquapin and two acorns—and introduced American walnut, Persian walnut and European filbert constitute the sources of edible nuts in this region.

C. E. SCHUSTER[1]

Introduction

EARLY settlers in the Pacific Northwest found the Indians using the few edible nuts indigenous to that section. These were the hazelnut (*Corylus californica* Rose), nuts from the evergreen chinquapin (*Castanopsis chrysophylla* Dougl.) and acorns from two species of oak (*Quercus garryana* Dougl. and *Quercus kelloggii* Newb.). The pioneers themselves regularly gathered and used the hazel and chinquapin nuts, but the acorns were used only in cases of dire emergency.

Chinquapin

The chinquapin is widespread throughout the area west of the Cascade mountains. It is most common in the foothills or lower mountains where it at times becomes very abundant. A few years after forest fires in such sections, small chinquapin trees can be seen even ahead of other native trees. The nuts are small, resembling a beechnut, and relatively hard shelled for that type of nut. The difficulty of extracting them from spiny burs, competition with squirrels, and the occurrence of worms in the nuts often make gathering of the wild crop slow and tedious. But in spite of that, these nuts have in the past been seen on the market. No attempt has been made to improve by culture or select improved types for commercial use so far as is known.

The chinquapin tree reaches a height of 50 to 100 feet. On the average, though, most trees will be found smaller. Value for lumber purposes is only fair, as the logs are too small. The evergreen foliage and general appearance of the tree cause it to be used occasionally as an ornamental shrub or tree.

Hazelnut

Wild hazelnuts were apparently used more extensively by the Indians and pioneers than were chinquapin nuts. The nuts, while small and very hard shelled, still produced more edible food and were more easily gathered. Until the cultivated filbert was regularly sold in the markets, wild hazelnuts for sale could usually be found in small quantities each year in spite of importation of the European filberts.

The wild hazel bush is quite variable in size. On a dry rocky hillside it may never exceed eight feet in height. On fertile river bottom soil, crowded by competing growth of other kinds of trees and shrubs, it has been reported to reach a height of 30 feet. No use is made of the wood in any form.

Acorns

The acorns of the Oregon white oak (*Quercus garryana*) and the California black oak (*Q. kelloggii*) were apparently

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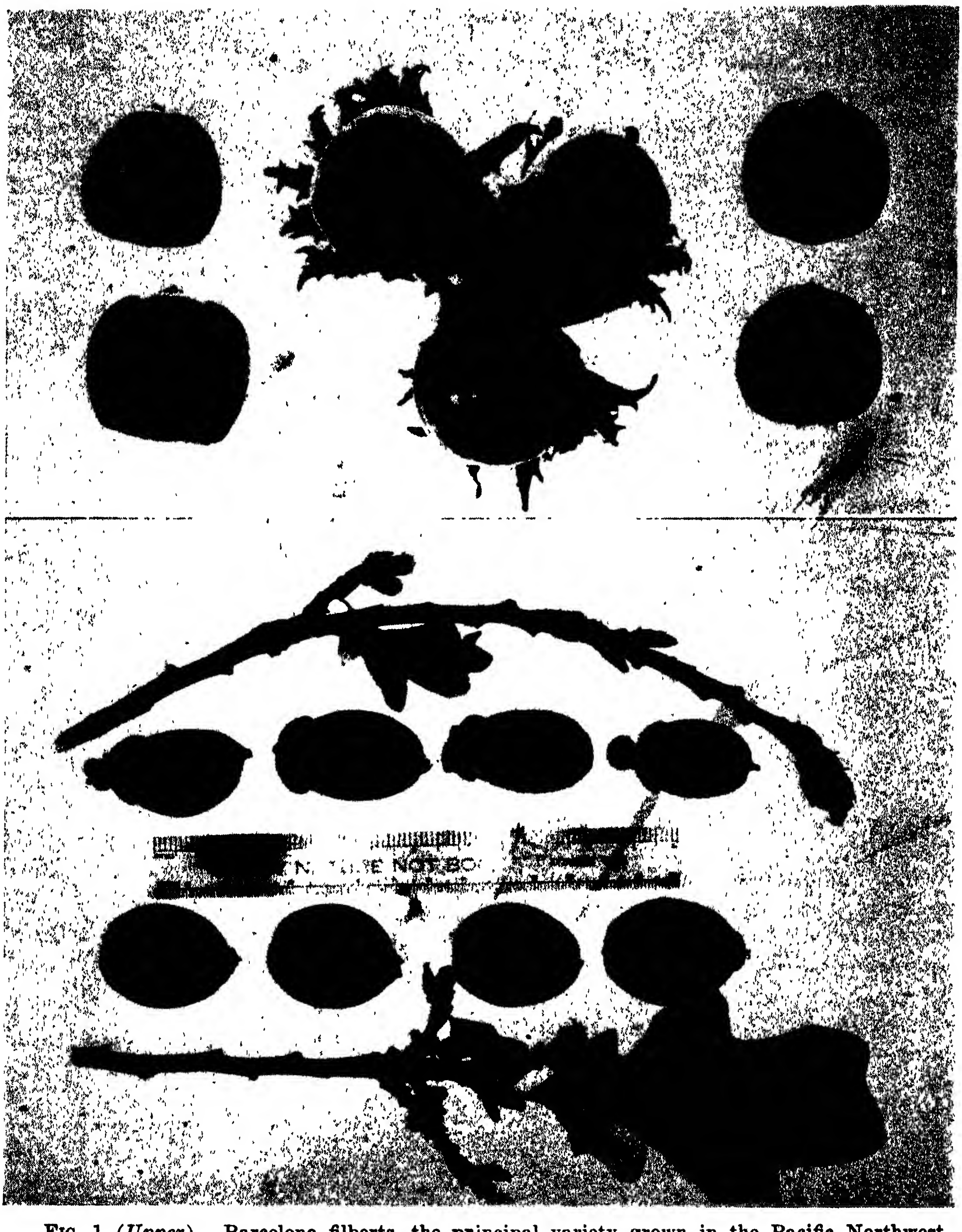

FIG. 1 (*Upper*). Barcelona filberts, the principal variety grown in the Pacific Northwest.
FIG. 2 (*Lower*). Acorns grown in southern Oregon.

in steady use by the Indians. Within recent years caches of such nuts have been plowed up where they were buried in wet ground to remove the tannin in the nuts. From limited information more use was made of the acorn in the southern part of the State of Oregon than in the northern parts. The north-

ern limit of the black oak is about in the Umpqua Valley of Oregon. The white oak is distributed from the northern to the southern boundaries of Oregon and northward through Washington, but the most productive areas are in the southern counties of Oregon. There the production of acorns is heavier and the size of the nuts larger than in the north, for instance, in the Willamette Valley. The lumber does not rate so high in value as does that of the white oak of other parts of the country, though it is used to a certain extent for furniture and similar purposes.

Walnuts

When the settlers came across the plains in the 1830's and 1840's they frequently brought along nuts of the black walnut (*Juglans nigra* L.), thus introducing this crop into the Pacific Northwest. When Henderson Luelling started his traveling nursery across the plains in 1847 he planted some black walnuts and hickory nuts in the wagon beds containing the nursery trees he was bringing to Oregon. These came up enroute and were undoubtedly distributed to the pioneers.

Soon after establishing the nursery at Milwaukie, Oregon, Luelling began growing Persian (English) walnut (*Juglans regia* L.) seedlings. The oldest surviving trees of this early date were planted in 1854 or 1856 near Scottsburg, Oregon, while one nut that was planted in 1855 near Dayton, Oregon, by Mrs. Joel Powell grew into an extremely large tree. Commercial plantings of Persian walnuts began in 1892 and were confined to seedlings, generally of French varieties. It was not until after the first World War that seedling trees were no longer sold and all plantings oonsisted of grafted trees, nearly all of the Franquette variety.

Varieties of Persian walnuts have been largely grafted onto seedling rootstocks of Hinds black walnut (*Juglans hindsii* Jeps.), commonly known as the Northern California black walnut. When white men came into northern California there were two small isolated stands of these trees which were soon cut down. Since then the nuts used by nurserymen have come from roadside trees. After the grafted trees reach an age of 15 to 30 years the union between the rootstock and the scion part of the tree often fail to form, and a layer of corky tissue develops. In a few years after this begins, the trees die. Many explanations have been suggested for this behavior. The most probable one seems to be that this trouble occurs when the rootstock is a hybrid; and since the seed parent trees are roadside or dooryard trees, usually not far away from Persian walnut trees, in many cases the seedlings are natural hybrids. Some have resorted to seedling rootstock grown from nuts of the Franquette to avoid this trouble, and others have rogued out the evident hybrids of the *Juglans hindsii* from the nursery. However, production of nursery trees for several years has been very small and of little commercial importance. Production of walnuts on the Pacific Coast has been rapidly increasing so that the marketing problem up to the time of World War II was very serious. With the advent of the war and the elimination of foreign imports the prices of walnuts rapidly rose, and walnut orchards were very profitable; but since the end of the war the market has been declining.

The tonnage of walnuts has been increasing steadily for years. The production in 1926 is given as 900 tons for Oregon. Since most of the limited tonnage of walnuts grown in the State of Washington has been processed at Oregon plants or marketed through sales agencies in Oregon, the tonnage of the two states has always been recorded as that of Oregon. The yield in 1946 is

given at 8,500 tons. In 1945, the last year for which farm values are available, a crop of 6,900 tons was worth $3,174,000 to the growers of this territory. Comparison of this with a yield of 900 tons valued at $450,000 shows the increasing importance of the walnut crop in the economy of this area.

In the early years of marketing all the walnuts were sold in the shell. As the tonnage increased and marketing became more difficult, a certain percentage of the nuts were cracked and the kernels sold direct to processors and manufacturers. The trend is more in that direction as time goes on, though it was interrupted by the war.

Such byproducts as walnut oil are negligible or non-existent. One product —ground walnut shell or walnut flour— is on the market commercially. Any other byproduct, if being sold at all, is marketed only in very limited amounts. However, byproduct possibilities are being explored intensively at this time.

As the walnut orchards became older and crowded, it was necessary to pull out part of the trees. Attempts to dispose of the trunks to make into lumber have been unsuccessful for the most part in Oregon. Even in the case of the black walnut, only the very old trees that are suitable for veneer material have found a ready market.

Walnut trees are planted in orchards at distances of 40 to 60 feet apart. The orchards are either the sole project of the owner or are a part of the farm. They are clean-cultivated during summer, and a cover crop is planted in the fall to plow down in the spring. The disease control work needed consists of spraying or dusting before and after full bloom, two to four times in all, to control walnut blight. Harvest is usually in October. The nuts are picked

FIG. 3. Harvesting scene in a walnut orchard in the Willamette Valley, Oregon.

from the ground on a piecework basis. Shaking the trees to bring down the ripe nuts may or may not be needed, depending on the weather. If there are numerous rains the nuts fall readily, free of the husk. After picking up, the nuts are thoroughly machine-washed and then dried in dryers. As time goes on commercial or cooperative dryers handle an increasingly large part of the crop. The nuts are then bleached, graded and packed according to the State grading laws and the demands of the market.

Filberts

Filbert growing has followed the same pattern of development as did walnut growing, except that it was two or three decades later in starting and, when once started, proceeded at a much more rapid rate. While walnut planting has nearly ceased for 15 years, filbert planting has been heavy, restricted in recent years only by the lack of availability of nursery stock.

In 1929 there was recorded a yield of 200 tons and in 1946 it was 8,950 tons. In 1929 the value of the crop was $60,000, while for the three years 1943, 1944 and 1945 the average farm value was $3,286,000 annually.

Filbert trees are planted at the rate of about 70 trees to the acre. Culture and care are essentially the same as for other nut trees. One or two spray applications are becoming necessary each summer to control the filbert worm. Nuts are picked from the ground. In the case of the Barcelona, the main variety in Oregon, the nuts fall free from the husk. In the case of DuChilly, the dominant variety in Washington, the nuts must be threshed out of the husks. As with walnuts, the nuts are washed after picking, then dried, bleached, graded and packed. All grading and packing is done in centralized plants. As yet, most of the nuts are sold in the shell, but the percentage of the crop that is cracked and sold as kernels is increasing rapidly. A few of the kernels in the past have been toasted, salted and sold in small packages. Such an outlet is again assuming importance.

The six-million-dollar walnut and filbert industry is contained in the area of Oregon and Washington that is west of the Cascade mountains and east of the Coast Range mountains of Oregon and the corresponding territory in Washington. Ninety per cent of the income flows into the Willamette Valley of Oregon. Walnut growing is carried on in a very small way in southern Oregon, and extends also into the southern counties of Washington. Filbert growing is on a limited scale in the Umpqua Valley in Oregon just south of the Willamette Valley. In Washington the filbert growing industry extends to the northern boundary and over into British Columbia.

With a small population in the Pacific Northwest, only a small part of the crop is consumed in this area; of necessity the rest must be disposed of in the large centers of population in the eastern part of the United States.

East of the Cascade mountains in Oregon there is no commercial industry in either walnut or filbert growing due to low winter temperatures and high temperatures in summer.

Attempts in Oregon to grow other tree nuts as they are grown commercially in other parts of the country have failed. Pecan trees grow well but have failed to bear. Production of almonds is very irregular, and the trees are so subject to disease that they are usually very short lived.

Red Squill—*Most Specific of the Raticides*

This bulb of the lily family is extremely poisonous to mice and rats but relatively non-toxic to domestic animals and humans.

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Introduction

ALTHOUGH the lethal effect of red squill bulbs on rats has been known and employed since ancient times to combat these pests by the peoples inhabiting the lands bordering the Mediterranean Sea, it has risen to prominence as a modern raticide only within the past 20 years. This was due largely to accelerated research on the utilization of red squill in rat control operations. In the United States steadily increasing amounts of this substance have been used in recent years, and renewed interest in red squill has been evidenced by practically all nations. The reason for this universal interest lies in the peculiar properties of red squill which render it the most specific of the raticides now available. Red squill, or squill, as it is commonly known, is toxic to and, when incorporated in suitable bait material, well accepted by rats, whereas domestic animals and humans find such a combination distasteful. In addition, squill powders, extracts and highly toxic concentrates of the active principles are strongly emetic in nature. Since rats cannot vomit they are unable to rid themselves of the squill, as do most pets and humans who readily vomit squill baits ingested accidentally. These two inherent characteristics coupled with the fact that squill is a slow-acting material makes it by far the safest of the lethal agents available to the general public for controlling rats.

The Plant

Red squill (*Urginea maritima* (L.) Baker), commonly referred to as the sea onion, is a plant belonging to the Liliaceae or lily family. It is native to countries bordering on the Mediterranean (Fig. 1) where the bulbs are harvested as a wild crop during the period of vegetative dormancy and usually just before flowering. The majority of the bulbs are sliced for drying, and the dried slices or "chips" exported, but a small portion of the bulbs gathered each year is exported for complete processing at the destination. Generally speaking, the potency of the bulbs varies with the locality from which they are gathered, the better quality for rat control purposes coming from Italy, Sardinia, Sicily and the Algerian Coast. The bulk of the squill imported into the United States during the last few years has originated from the latter source.

Mature red squill bulbs resemble a large onion in structure (Figs. 2–4). They are composed of overlapping fleshy scales, the outer being a reddish brown, and the interior varying in color from a light yellow to a deep purple. The scales of the central core are usually white. The bulbs of commerce ordinarily weigh from two to eight pounds, but some which have been grown for a period of years in this country have attained a weight of 20 pounds.

The plants produce their vegetative growth, consisting of deep green, blade-like leaves, in the fall and winter during the rainy season, and become devoid of foliage in the late spring and summer, a period when rainfall is practically nil in

the Mediterranean regions where squill abounds. During the period of dormancy when the plants are without leaves, usually in midsummer or early fall, a single stalk bearing a raceme of many flowers emerges and rapidly grows to a height of four or five feet (Fig. 2). The small white flowers have a narrow, light yellow-green stripe running longitudinally the length of the petal. A small band of flowers blooms each day progressively up the raceme; the number blossoming on any one day may vary from one or two up to as many as 50 or more. The fruit is a three-celled capsule with flat, black, slightly winged seeds having a thin, fragile shell. Individual seeds were found, on the average, to weigh about two milligrams, and when hand pollinated, one flower stalk produced approximately 4,800 seed.

In addition to the red squill, a white variety is also available commercially. White squill is used in human medicine as a heart tonic and nauseant expectorant. These two varieties apparently present no botanical differences. Although microscopical examination of powders prepared from red squill may reveal cells containing red pigment, and those from white squill usually lack them, the biological reactions of these substances are the most reliable basis of differentiation.

Whereas red squill exhibits the same general properties as white squill, in addition, it contains toxic glycosidal compounds which are generally referred to as the "rat-killing principles". In 1942 two Swiss chemists reported the isolation of the "rat-killing principle" of red squill in crystalline form. The compound scilliroside isolated by these workers (1) was found to contain glucose, and its extreme toxicity to rats is emphasized by the fact that the average lethal dose of the crystals for male rats is only seven-tenths of a milligram per kilogram of body weight. Thus, it will be noted, the toxic principles of red squill, in their purified form, are among the most potent of rat poisons. Whether scilliroside is the only compound in squill that is toxic to rats, remains to be determined.

The tissue of both squills contains minute needle-like crystals or raphides of calcium oxalate usually embedded in mucilage. These crystals are essentially non-toxic but are a factor in the nettle-like irritation which squill powders cause when they come into contact with the skin or mucous membranes. The irritation caused by squill preparations no

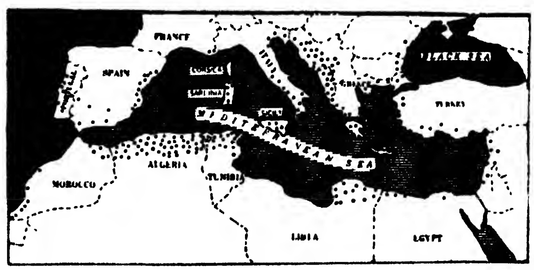


FIG. 1. Geographical distribution of red squill.

doubt contributes to the objectionable taste of squill baits which is evidenced by most animals except rats and mice. This acrid taste together with its slow toxicological action and its emetic nature combine to render red squill comparatively harmless to domestic stock, pets and humans.

Preparation and Toxicity

Since crude red squill powder, the ordinary article of commerce, is prepared by merely drying slices of red squill bulbs which may come from a number of sources, great variations in toxicity are encountered when different lots of powder are tested biologically. Indeed, the toxicity of individual bulbs harvested simultaneously from the same region and indistinguishable by visual inspection were found to vary in all degrees from highly potent to impotent. A consider-

FIG. 2. Essential vegetative features of red squill. (From a water color plate by Ida Hrubesky Pemberton, Denver, Colorado.) 1. Mature red squill bulb with flower stalk. 2. Leaves. 3. Year old seedling. 4. Two-year-old seedling. 5. Longitudinal section through the center of mature bulb. 6. Leaf scale after planting in sand bed, showing asexual origin of small bulblets along the basal edge. 7. Stamen and flowers. 8. Pistil and ovary. 9. Seed pod and seed. Sections 7, 8 and 9 are drawn to a larger scale than the other elements in this plate.

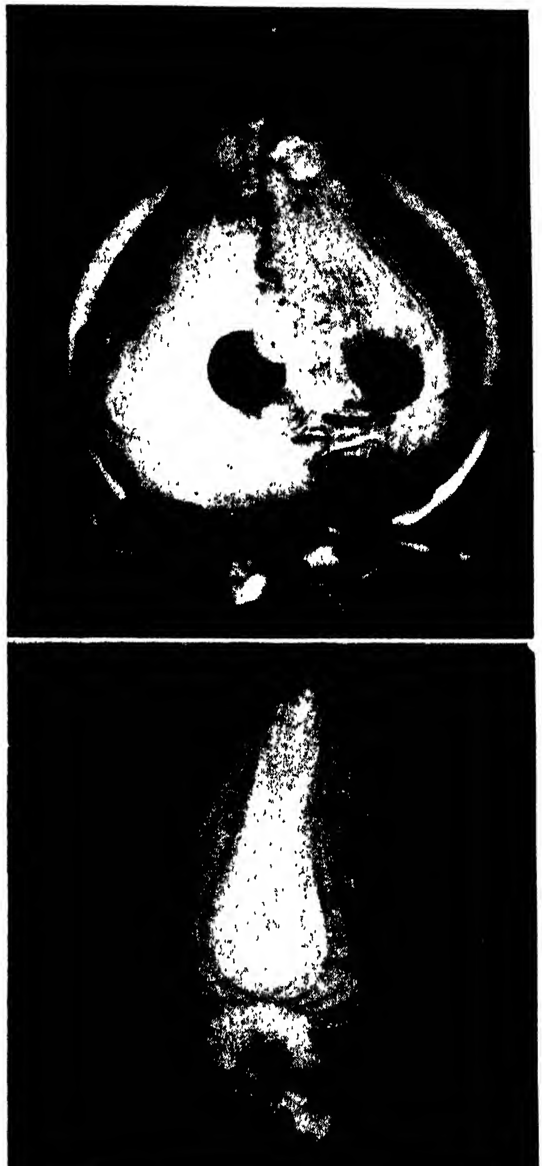
able portion of the bulbs from any one area apparently fall into the latter category. From this it is apparent that only a small percentage of highly toxic bulbs are ordinarily incorporated into crude commercial powders. As a result some crude powders tested in recent years were found to have a toxicity such that 400 mg./kg. sufficed to kill male rats, while others required as much as 3,000 milligrams of powder per kilogram of body weight to produce death. Translated into grains per pound the above dosages become approximately 2.8 and 21, respectively. White squill has failed to kill rats when administered in doses as high as 5,000 mg./kg., and for all practical purposes is considered to be non-toxic to rats.

As the male rat is much more resistant to the action of squill than the female, the former is most commonly used for testing squill products. In accurate bioassays, calculation of the dosage mortality curve (3) is the usual method employed to determine the LD 50% point.

Several factors are known or suspected to influence squill bioassays: the strain of albino rats employed, the age of the test animal, previous diet fed and the altitude at which the bioassay is conducted. Of the factors mentioned, the strain of rat used is probably the greatest single cause of the variable results often reported when identical samples are assayed at different laboratories.

Propagation of Red Squill Bulbs in the United States

During the past six years the Wildlife Research Laboratory at Denver, in cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering, Department of Agriculture, has made experimental plantings of red squill bulbs in the regions of the United States where mild winter temperatures prevail. From several years observation of the progress made by bulbs planted in selected spots across the southern United States from Florida to California, it appears that red squill grows best in the coastal regions of southern California from Camarillo south to Ensenada, Baja California, Mexico. It is in this area that the climatic pattern and rainfall parallels that of the Mediter-



FIGS. 3 & 4. Method of plug sampling. The holes are filled with paraffin before the bulbs are replanted.

ranean regions to which squill is native. The Foreign Economic Administration assisted in 1944 by importing 1,500 mature bulbs from Algeria for propaga-

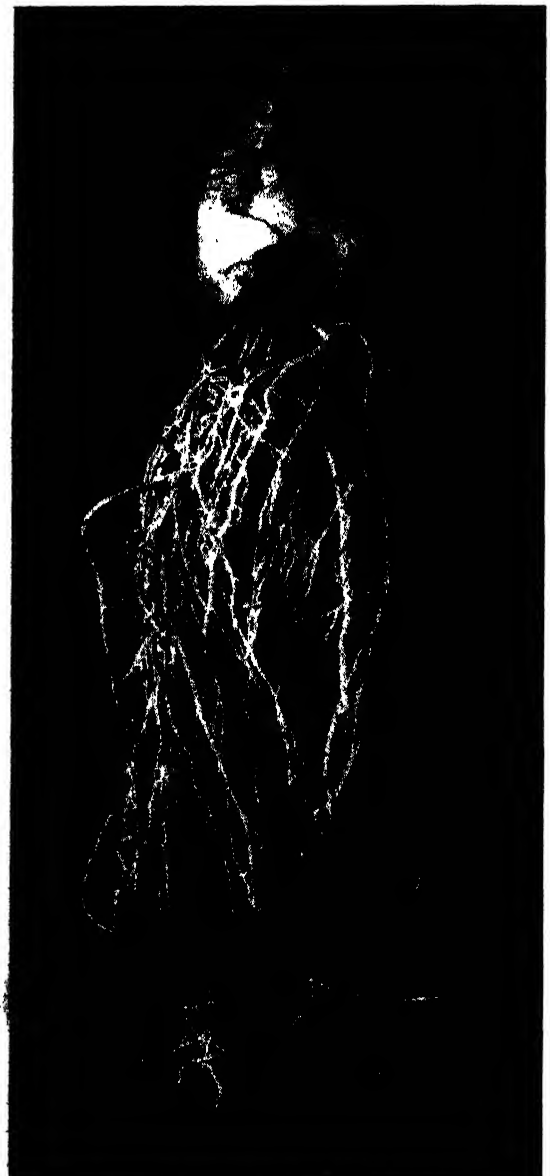


FIG. 5. Root system developed in one season by a mature red squill bulb when grown in a large flower pot.

tional studies in the western hemisphere. These, after being plug sampled (Figs. 3 and 4) at Denver for a toxicity determination of each bulb, were sent to Ensenada, Mexico, where they were grown under observation for two years (Fig. 6). In 1946 the bulk of the bulbs were transferred to the Torrey Pines Station of the Bureau of Plant Industry, Soils, and Agricultural Engineering near San Diego, California, where propagation studies will be continued. Efforts are being directed through selection and breeding experiments toward the development of a strain having a uniformly high toxicity and other characteristics suitable for domestic cultivation on a commercial scale. Propagation is effected by means of bulb cuttings and seed (Fig. 2). Unfortunately, several years are required to produce mature bulbs from seed or by the cutting method, and because of this fact red squill development will of necessity be a long term project.

Standardization and Fortification of Red Squill

As the utilization of red squill in rat control increased, efforts to fill what in reality constituted an abnormal demand for this commodity led to the collection of squill from all available sources. Quality soon became of secondary importance, and the average potency of sun-dried chips and of bulbs reaching the United States fell to a point where it could no longer be used effectively as a rat control agent.

Faced with a huge supply of poor quality squill already on hand in the country and an accelerated need for rat control, the Denver Wildlife Research Laboratory of the Fish and Wildlife Service investigated the problem at some length and developed a method for fortifying this type of squill with suitable extracts prepared from a portion of the same low grade material to a level of toxicity at which it could be employed against rats with efficient results. The method (2) consists essentially of an intermittent, counter-current extraction of powdered red squill with an 80% ethyl-

alcohol-water solution. Three extraction cells were incorporated into the extraction process and the solvent routed through the system in such a manner that each charge of squill was extracted five times. The final extract was concentrated in vacuo and proved to be several times more toxic on a dry weight basis than that accomplished by merely extracting a single batch of powder with five separate lots of fresh solvent. The extract obtained from the counter-current process, after concentration, is mixed with a predetermined amount of unextracted powder, the mixture dried at 80° C., and the dried squill "cake" then re-milled to a 20-mesh or finer powder. "Fortified" extracts can be prepared by merely diluting the concentrated extract with glycerine or any other suitable diluent to a desired toxicity level. Preservatives, *e.g.*, sodium benzoate and salicylic acid, are added in small quantities to fluid extracts to enhance their keeping qualities. Control of the process as well as determination of the toxicity of the final product is carried out by bioassay procedures using male albino rats as test animals.

The fortified product, powder or extract, retains all of the safety factors present in crude squill powders and, when fortified to a satisfactorily toxic level, will, when properly used, effect an efficient degree of rat control.

As demonstrated by actual operations, the more toxic the squill preparation used in the baits the greater the degree of control attained. In this respect, squill powders and extracts having an LD 50% for the male rats (lethal dose killing 50% of the test animals) of 600 mg./kg. have given satisfactory control when incorporated into highly attractive bait materials which were then carefully exposed. However, a 400 mg./kg. squill is a more desirable product in that the animal ingests a lethal dose upon consuming less bait than is required when a less toxic squill is employed. An added advantage in using the more potent squills lies in the fact that less attractive and generally less expensive bait materials can be used with this type of product.

Effect on Rats

Rats that have eaten a fatal dose of red squill exhibit a train of symptoms which indicate that it acts primarily on the central nervous system. Within one or two hours after the ingestion of a killing dose the rat becomes lethargic and shows signs of irritation about the mouth and nose. After a short period tremors and paralysis of the hind legs appear. The paralysis progressively involves the trunk and forelegs, and the breathing becomes labored. At this stage intermittent convulsions in which the rat rolls over and over or rotates

Fig. 6. Sand beds for propagation of red squill by cuttings. This work was conducted by the Foreign Economic Administration near Ensenada, Baja California, Mexico.

on its longitudinal axis provide the most characteristic symptom of red squill poisoning. During the convulsive phase, a rat, quietly resting, may be thrown into a series of gyrations by merely disturbing the cage. The convulsive period may last from a few hours up to several days and is followed by prostration. Death results largely from respiratory failure. Upon post-mortem examination there is pronounced irritation of the upper digestive tract, but this is not extensive enough to be fatal.

Effect on Other Animals

The statement that red squill is relatively harmless to humans and domestic animals has been repeatedly substantiated both in this country and abroad. This is due in the main to the reluctance of animals other than the rat or house mouse to eat baits containing red squill. This has been found to hold even when animals have been kept under conditions of enforced hunger and the regular diet combined with red squill was the only food available.

Horses and ruminants, such as cattle and sheep, as a general rule, almost completely refuse food items contaminated with red squill. The size of these animals affords them additional protection because of the large amount of a 10% red squill rat bait that would be required to produce a toxic reaction.

Pigs normally show a marked aversion to red squill, and it is quite unlikely that hogs will voluntarily eat enough of a red squill rat bait to provide a lethal dose. One-half pound or more of a red squill rat bait would be required to kill an adult hog.

Dogs and cats, particularly the latter, consistently refuse red squill baits, and if eaten profuse vomiting usually is the only consequence.

Pigeons were found to refuse food containing red squill, and crop vomiting was the only response when red squill was injected directly into the crop.

Chickens proved very resistant to the action of red squill, although they readily eat red squill when it is combined with their food. In this regard, adult chickens have been maintained in good health for long periods when 10% red squill was added to the daily ration. It is unlikely that baby chicks will eat enough red squill bait to cause injury.

Field rodents, such as the prairie dog, pocket gopher or woodchuck, refused to eat toxic quantities of red squill baits.

House mice do not hesitate to eat red squill baits, but due to the feeding habits of this animal an effective degree of control through the use of red squill is not often attained. The house mouse tends to feed frequently and usually takes only small amounts of food at each feeding. In view of this peculiarity, it is probable that sufficient time may elapse between feedings to allow the initial symptoms of red squill to develop and thus prevent the consumption of a lethal dose of bait through subsequent feedings.

Under conditions of forced feeding or stomach tube administration, it has been demonstrated that red squill is about equally as toxic to most animals as it is for the rat. Protection from red squill is afforded by the marked unwillingness of most animals to accept food containing it, by its producing vomiting in those animals which are able to vomit and by its being more or less non-toxic to some forms, for example, poultry. Since the total amount of red squill necessary to produce toxic symptoms or death in any animal varies with its weight, the larger animals find additional protection in that relatively large quantities of a 10% red squill rat bait must be ingested to cause serious effects.

Below are some of the approximate lethal doses of red squill which have been listed in the literature or which were obtained through forced feeding or stomach tube administration of red squill to various farm animals. For comparative

purposes the toxicity of the squill used is also given for rats:

ANIMAL	LETHAL DOSE IN MILLIGRAMS OF RED SQUILL PER KILOGRAM OF BODY WEIGHT
Cattle	200
Horses	200
Sheep	200
Pigs	200
Rats	200

Accidental ingestion of red squill rat baits by humans has occurred many times with vomiting the only discomfort encountered. As an experiment, one individual took 40 grains of red squill powder. Nausea and vomiting occurred within 15 minutes and no other symptoms developed.

Although red squill can be used about the home or farm with little danger to individuals or domestic stock, it must be remembered that if the baits are eaten or scattered by animals other than those for which they were intended, they may no longer be available for killing rats. It is also possible that under some conditions which have not as yet been fully investigated the irritant qualities of red squill may prove hazardous to animals not in good health. For the above reasons it is obvious that insofar as possible, red squill baits should be placed in such a manner that animals other than rats and mice will not have ready access to them.

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Utilization Abstracts

Jojoba. In the desert regions of the southwestern United States there is a shrubby plant, up to four feet tall and known as goat nut or jojoba (pronounced "hohoba"), that has possibilities as a commercial source of oil. The seeds contain about 48% of oil which has been used locally as a hair tonic, and an old Spanish account of 1789 attributes medicinal virtues to the plant, holding it to be a cure for wounds and a remedy for cancer. The acorn-like fruits have long been eaten by Indians and others, and cattle are fond of both fruits and leaves.

In 1933 it was discovered that the so-called oil in jojoba seeds is a liquid wax, as is sperm oil; all other known seeds contain fatty or glyceride oils. Patents have been issued on a rubber-like substance made from the oil; on use of the oil in shortening and other food products to delay their becoming rancid; and on use of it in printer's ink and as a lubricant for delicate instruments. Application for a patent was made about six years ago to cover the hydrogenated wax which is suitable for candles, since candles made from it do not melt before being used, even in the hot Arizona climate. In hardness jojoba ranks next to carnaúba wax and competes with it in some uses.

After the oil is removed from the seed the residue is suitable for stock feed and can be used also in plastics. A beverage has been made from the ground and roasted seed, and sometimes the fruits are eaten directly from the bushes.

In the spring of 1946 at least one ambitious commercial planting of jojoba was undertaken in the Southwest, but before the end of the year it was abandoned to a large extent. (*Margaret Douglas, Jour. N. Y. Bot. Garden 48: 29. 1947*).

Botanical Drugs—*A Brief Review of the Industry with Comments on Recent Developments*

Old-World sources of botanical drugs are still foremost, despite attempts during the two World Wars to develop American sources of Digitalis, Juniper berries, African peppers, Spearmint, Peppermint, Belladonna, Rhubarb root, Arnica flowers, Stramonium, Chamomile flowers and Fennel seed.

E. F. WOODWARD

S. B. Penick & Company, New York, N. Y.

Early History

THE history of the crude drug industry, both the commercial and technical aspects, probably began with the first barter arrangements between an ailing clan member and the corner witch doctor.

The earliest graphic records contain references to plants being cultivated or collected for use in medicine. A few hundred drugs were known to the Assyrians in 2500 B.C., and the famous "Papyrus Ebers" of 1600 B.C. records many Egyptian medicines and preparations then in established usage. Arabic writings dating from 1300 to 700 B.C. also contain numerous references to work in natural history, including medicinals, and the activities of Alexander the Great, naturalist, should be recalled as important contributions of the years around 320 B.C.

About 75 B.C. the outstanding work of the era was published—"De Materia Medica"—authored by Dioscorides, the renowned Greek physician. This work considered in detail several thousand botanicals and remained the authority for 15 centuries.

The next significant advances were made in comparatively recent times, being the works of Brunfels, Valerius, Cordus, Linné, and the fundamental studies in comparative plant anatomy by Schleiden.

Pharmaceutical botany and pharmacognosy, as we know them today, had their commencement in the writings of T. W. C. Martius and O. Berg, and later in the 1800's of Oesterle, Fluckiger, Moeller, Hanausek, Gilg, Tschirch, Hanbury, Greenish, Wallis and Von Mueller. These men were all continental Europeans with the exception of Greenish and Wallis who were British. The prominent early Americans active in this field were Millspaugh, and Bentley and Trimen. At the turn of the twentieth century, Rusby and Kraemer came to the foreground.

Concurrent with these scientific pursuits were important discoveries made in less learned circles. The first radiologists were the natives of the Belgian Congo who obtained seemingly miraculous cures for certain bodily ailments when they immersed themselves in selected wallows. Radium was later extracted from ores mined in these areas. The ancient Chinese healed suppurating wounds with green molds—penicillin in its infancy. And then there was the famous Shropshire housewife who sug-

gested the present medicinal usage of digitalis in heart disorders.

Witch doctors, folk-lore and old-wives-tales have all made valuable contributions to our present Materia Medica. Some of their remedies have fallen into disrepute, but a few valuable contributions remain.

As various explorations broadened the geographical horizons, new medicines were introduced into practice. First they were offered for sale from the ship's cargo, later imported by general merchants, and in the last few hundred years importers handling drugs exclusively came into prominence—first in Europe, then England and lastly in America.

At the same time, the apothecary was extending his operations to include merchandising wholesale quantities of drugs. A combination of these two fields was now a logical step. Most of the American companies started out as commission houses, small importers or, like ourselves, as collectors and merchants of domestic botanicals. It was a natural expansion to include imported drugs, insecticides, gums, spices, essential oils and resins as well as plant derivatives, such as glycosides, alkaloids, oleoresins and many other items of related origin.

A group of sales invoices from those times would show a peculiar assortment of transactions, such as carrying Ergot[1] from Europe for obstetrical use by a pharmaceutical manufacturer, gum tragacanth (*Astragalus* sp.) from western Asia and southeastern Europe for a manufacturer of printed textiles, cuttlefish bone (*Sepia officinalis* L.) for a pet shop to sharpen parrots' beaks, pyrethrum (*Chrysanthemum Leucanthemum* L.) from Africa for control of agricultural insect pests, juniper berries (*Juniperus communis* L.) from central Europe for a gin distiller, sage leaves (*Salvia officinalis* L.) from central Europe for the butcher, poppy seed (*Papaver somniferum* L. var. *nigrum* D.C.) from Holland for the baker, and gum olibanum (*Boswellia* sp.) from Arabia for the candlemaker.

[1] Ergot is the dried sclerotium of the fungus *Claviceps purpurea* (Fries) Tulasne developed on rye plants infested by it. See article on ergot in this issue.

Uses, Sources and Variety of Drugs

It is interesting to note that some officially recognized drugs find their greatest use in fields other than pharmacy or medicine.

Licorice root (*Glycyrrhiza* sp.) from southeastern Europe and the Occident, for instance, is used primarily by the tobacco industry, secondarily by confectioners and least of all in medicine. As for soap bark (*Quillaja Saponaria* Molina) from Peru and Chile, every time a pound finds its way into a pharmaceutical, a ton goes to industrial users in many lines, for example, the manufacture of fire-extinguishing solutions. And karaya gum (*Sterculia* sp.) from Persia is vastly more important to the food industries than it is to pharmaceuticals. But before the reader is misled, we hasten to say that the majority of drug sales has a very definite leaning towards the side of medicine. There is hardly a dicotyledonous plant family in Engler & Gilg's list which does not contribute to the Materia Medica. Every plant part is represented in one or another drug, and with some plants, various parts or a combination of parts are used. Roots, stems, leaves, flowers, fruits, seeds, rhizomes, bulbs, barks, flower buds, pollen, all these and other organs or tissues are to be found.

Geographically speaking, the world is our garden, both the land and water areas—cod-liver oil for vitamin nutrition from the Arctic, buchu leaves (*Barosma* sp.) for urinary disorders from Capetown, Moroccan coriander seed (*Coriandrum sativum* L.) for flavoring purposes,

and kava kava root (*Piper methysticum* Foster) for its diuretic qualities from opposite points on the equator.

The extremes of time yield their valued products: Diatomaceous earth for filtering purposes is obtained from deposits several million years old, and sweet-scented Balm of Gilead buds (*Populus candicans* Aiton, *P. Tacamahacca* Miller), as an ingredient in cough medicines, are gathered in the early spring before they start to open.

There are big plants and little ones: eucalyptus (*E. globulus* Lab.) the oil of which possess a variety of pharmaceutical properties, and drosera (*D. rotundifolia* L., *D. anglica* Hud., *D. longifolia* L.) used as an expectorant in bronchitis and coughs; big parts and little ones: quassia logs (*Picrasma excelsa* (Swartz) Planchon), the infusion of which serves as a bitter tonic; and the spores of lycopodium (*L. clavatum*), used as a protective dusting powder for pills and in fireworks.

Some items, *e.g.*, chamomile flowers (*Matricaria Chamomilla* L.), of domestic and European production, a tonic and gastric stimulant, require little handling at their source of origin other than drying and packing for shipment. On arrival at New York such medicinals are sold mostly in original packing, although some quantities are repacked into considerably smaller units, such as five pounds, or as little as one ounce.

FIG. 1. A scene in the mountains of North Carolina, near Asheville, where considerable botanical material is collected for processing in the drug industry.

Digitalis leaves (*D. purpurea* L.), also of domestic and European production, require expert harvesting, drying and special packaging to insure retention of

maximum potency and to comply with official standards.

Senna pods (*Cassia Senna* L., *Cassia angustifolia* Vahl.), from the Sudan and India, for use as a purgative, and juniper berries require hand-picking to produce top quality material. Cardamon fruits (*Elettaria Cardamomum* Maton) for flavoring, from India, must be graded and usually are bleached before packing. Numerous other items receive some degree of grading, picking, sorting and cleaning, with much of the work done by hand or by the use of rather primitive machines.

Some items require a curing process to prepare them for market. Gentian root (*Gentiana lutea* L.) from France and Spain for use in tonics, and kola nuts (*Cola nitida* and other sp.) from Jamaica, Nigeria and Liberia for their stimulating quality are good examples. Gentian is a well established simple bitter—one of the best. The roots are collected from plants two to five years old, and more. These roots (and rhizomes) are gathered into mounds and allowed to dry and ferment slowly. The internal color slowly changes from white to medium brown, and the characteristic odor and taste develop.

Kola nuts are the fleshy cotyledons of the seed. When fresh, their internal color is comparatively light, but on exposure to light and air, the color gradually darkens, as does a slice of fresh apple, until it becomes a dark reddish-brown. The dried kolas are quite hard and tough.

Most of the manufacturing is carried out with the crude materials after arrival in the United States, one very good reason being that milled drugs are dutiable at 10% ad-valorem, whereas most crudes are free of duty. Another reason is the lack of special machinery and skilled labor in the producing areas, with the resultant lack of economical operation and, even more important, the absence of stringent quality control in foreign areas.

Practically all drugs require some milling on arrival to make them ready for the manufacturer or other consumer. Sifting, reconditioning, grinding, cutting, powdering, grading, blending and many other types of specialized machine processes are required to produce the varied finished goods.

Although it is not within the province of the industry to manufacture such classes of finished drug products as tablets and pills, tinctures and syrups, it is often of service to facilitate operations for pharmaceutical manufacturers by changing the crude drug into a more readily utilizable product such as an oleoresin or an extract. Extracts represent the total soluble constituents of the original drug and are produced by maceration, percolation, filtration and evaporation to a consistency resembling that of honey, or to a solid which is powdered before packaging. Kola nuts are frequently processed in this manner. Oleoresins of capsicum (*C. frutescens* L.), from Louisiana, Zanzibar, Mombasa, Nyassaland and Sierra Leone for use as a stimulant and condiment, are mixtures of the volatile oils and the soluble resins in the crude. They are obtained by percolation with ethyl alcohol or some similar solvent, filtration and evaporation. As with extracts, low heat and a high vacuum facilitate the evaporation process.

Concentrations, another type of product, are manufactured by precipitating out of an alcoholic solution mixtures of certain active resinous principles of an indefinite nature, as with leptandra (*Veronica virginica* L.) of the Southern Appalachians, from which leptandrin is made for use as a cathartic and emetic. This is accomplished by pouring a concentrated solution into water, then separating and drying the precipitate.

Jalap root (*Exogonium purga* Wen-

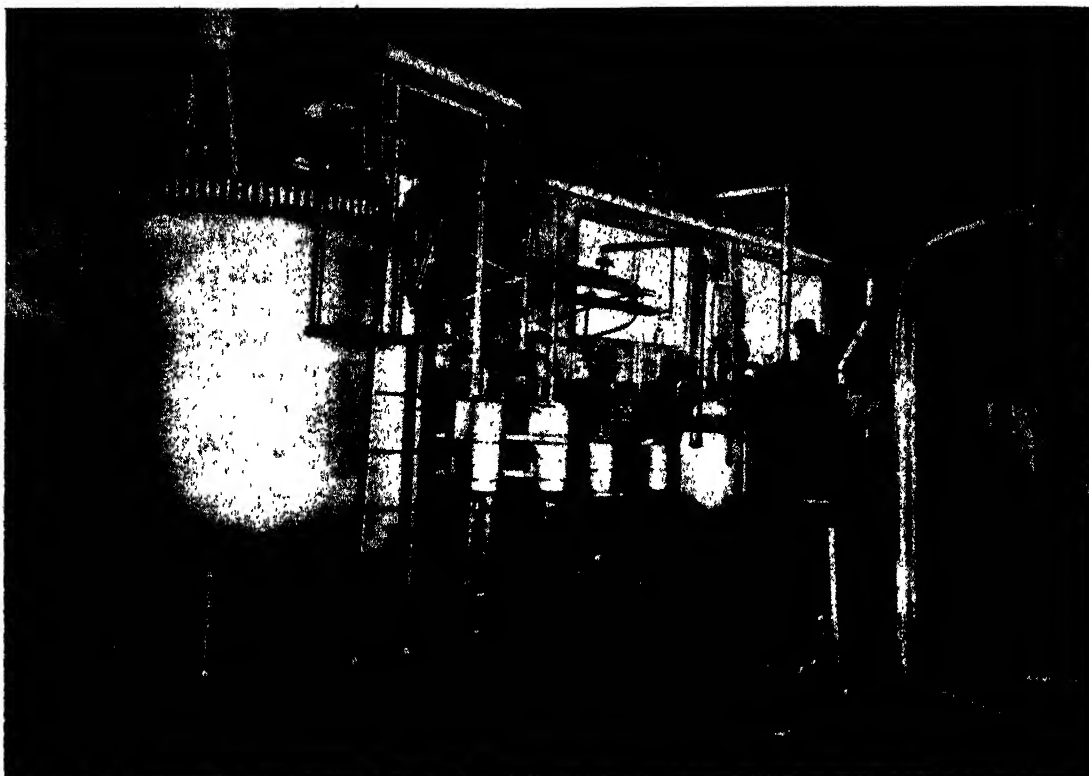

FIG. 2 (*Upper*). A portion of the equipment necessary for modern high-fractionation processing of botanicals. FIG. 3 (*Lower*). Some of the modern equipment employed in alkaloid-finishing operations of botanicals.

deroth) Bentham from Mexico for cathartic use and other plants are extracted of their resins in a manner similar to the production of oleoresins.

When only one active principle is desired, more delicate operations are in order. Various members of the Solanaceae (*Hyoscyamus muticus* L., *Datura Metel* L.), for instance, are granulated, extracted by means of immiscible solvents, evaporated and re-extracted with a volatile solvent to yield such valuable

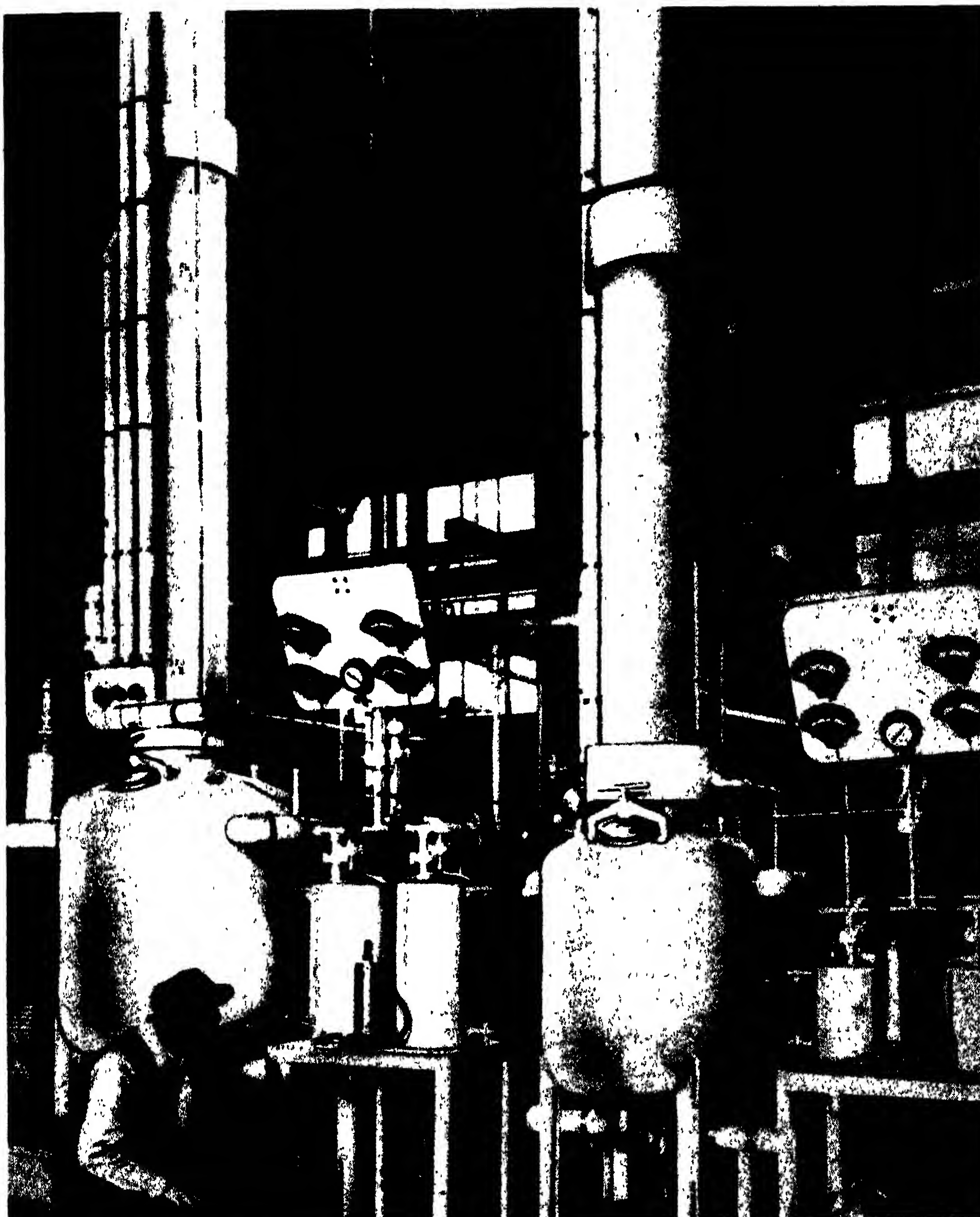

Fig. 4. Other equipment in a high-fractionation department.

alkaloids as atropine and scopolamine, which are crystallized and recrystallized by means of appropriate solvents. If an acid salt is desired, such as the sulfate, the properly acidulated aqueous solution is crystallized.

It is difficult to give a general procedure for the manufacture of glycosides, as the method varies with the stability of the product. Some are obtained by precipitating an aqueous extract with tannic acid, removing the precipitant as an insoluble metal salt and crystallizing from the purified aqueous solution.

On the surface these operations might appear to be relatively simple, but in actual practice the various procedures become an art and a science learned only after long apprenticeship and years of experience.

Various aromatic plants and plant parts are steam-distilled to yield their valuable essential oils. Usually redistillation and/or fractionation is a necessary step in the production of an oil of high quality.

As one thing leads to another, the manufacture of synthetic perfume and flavoring materials follows, as does the production of heavy organic and metal-organic compounds. Many so-called "synthetic aromatics" are derived from chemically related crude materials of natural origin. It becomes evident that although the crude drug industry is mainly concerned with botanicals, several other classes of items are dealt with. These other groups are mentioned occasionally in this article in order to leave a more accurate impression.

Rutin is another item of interesting manufacture which is currently obtained from green buckwheat. This chemical, regarded as a vitamin-P analog, has recently enjoyed an upsurge of popularity in medical circles for treating capillary fragility.

From the soil we get *Bacillus brevis* which is used in cultures to produce tyrothrycin, recently discovered as being of considerable value as an antibiotic. Many botanicals are presently being screened for their possible value as antibiotics.

By these, and other processes, a 300-pound bale of leaves is reduced to a few ounces of alkaloid; a ton of flowers becomes a small flask of oil; or the pungent capsicum is concentrated in potency to the tongue-tingling peak of "red dynamite".

Drug Identification and Evaluation

Identification and evaluation of crude drugs constitute both an art and a science. Many of the finer points of evaluation are learned only through long experience, as is the case with tea-tasters, perfumers and similar artisans. Drugs, once identity has been established, are judged solely according to their physical and chemical analyses, and the services of chemists, pharmacognocists, pharmacologists and physicists are all necessary in carrying out this work.

Primary identification is usually based on botanical, or more specifically, pharmacognostical methods. There is no such practice as "keying-out" a root or a bark. Identification is based on visual and microscopical inspection, later to be checked by chemical and other means. This procedure is reliable whenever the item in question is reasonably well known and established, but if the root or bark, or other plant part, is a new item, purely botanical methods are employed, working from herbarium specimens.

Quality and purity are judged by these same methods plus chemical and microchemical tests, biological assays and examination by physical methods, employing such apparatus as the ultraviolet light.

Intentionally, or by accident, botanical drugs are subject to contamination, adulteration and substitution. As for

contamination, this is usually the result of ignorance or carelessness on the part of the producer or collector. Occasionally drugs become contaminated with foreign odors or flavors from other merchandise stored close by. Inclusion of more than the allowed percentages of foreign organic or inorganic matter is classed as adulteration. For example, 5% of stems are allowed in ipecac root (*Cephaelis acuminata* Karsten, *C. Ipecacuanha* (Brotero) A. Richard) from Brazil and Central America for use as an emetic, and inclusion of a higher percentage would be regarded as adulteration. The borderline between contamination and adulteration is rather finely drawn, especially in legal circles. If the adulteration is intentional, the unscrupulous producer usually resorts to the cheapest and most convenient material at hand. Odd lots of such items from the fields or warehouses, or any other substance that the seller can introduce, are utilized if the seller believes there is little chance of detection. Rocks, stones and scrap iron are now less frequently encountered, but occasional attempts are made with an embarrassing lack of success. Experience shows there to be no such thing as a "common" adulterant if the introduction is intentional. Substitution of some other item, in whole or in part, occasionally happens. Here again, ignorance of the shipper is usually the cause. Several drugs are subject to substitution whenever easily mistaken unwanted plants of similar appearance grow in the same area with the proper species.

Domestic Cultivation and Gathering

The botanical drug industry was both handicapped and stimulated by the two World Wars. Because certain plants are indigenous to relatively small areas, or because only those obtained from certain areas are of medicinal value, or because it is economically practical to produce or collect only from certain areas, most nations are, comparatively speaking, pitiably reliant on other nations for their requirements of crude drugs. During World War I the Americas sought a solution to this situation with varying degrees of permanency and success.

Cinchona was indeed a proverbial "thorn", as will be seen later, and it was not until the second war that the United States had any degree of independence from the production of this material in the East Indies.

Before the close of World War I certain shortages in drugs, other than that of cinchona, were lessened by domestic cultivations. African peppers were grown in South Carolina, spearmint (*Mentha spicata* L.) and peppermint (*Mentha piperita* L.) in Wisconsin and belladonna (*Atropa Belladonna* L.) in California to a limited extent, while digitalis was collected from wild growth in Washington and Oregon.

All these efforts had their basic obstacles. Food crops were of paramount importance throughout the world. High labor costs in the States were a serious economic handicap to most projects. Propagating material was difficult if not impossible to obtain. Natural habitats were difficult to satisfactorily duplicate. Perennial herbs and woody plants were slow to yield a harvest.

When World War II materialized there was a body of experience and a nucleus of former productions. There was the realization that much work had to be done and that several years would pass before the opening up of former sources of supply. Here, time prodded with an urgency and an ominous warning as to the consequences of shortages in critical materials.

When the probable geographical extent of the war and its possible duration became apparent, considerable effort was expended to plan some relief from the

inevitable scarcities. After the expenditure of concerted effort by field men, two important domestic collections were started, digitalis leaves and juniper berries.

Digitalis was formerly imported in quantity from southern Europe, especially the Balkans. It is not uncommon in other countries also, and it is well known in many flower gardens as the popular foxglove. Fortunately it grows rather profusely in the foothills of Washington and Oregon. Although it meant higher prices, due to the cost of domestic labor, sizable quantities were collected in these two States.

Not being satisfied with the uneven quality and the mounting costs, the domestic cultivation of this highly valuable plant was undertaken. The first real crop of digitalis was harvested in 1946. Because the plant lends itself to mechanized agriculture, and because of the steady demand, its cultivation will probably be continued.

Disregarding the economic risks being taken, careful plans for greatly increased production were laid for 1942. Acreage was contracted for in Pennsylvania, New Jersey, Ohio, Tennessee, Wisconsin and Virginia. Greenhouse space was obtained after much effort from nine nurseries. Five million belladonna seedlings were grown, transplanted twice by hand and rushed to 216 farmers for setting out in the fields. Special dryers were built, each of which could efficiently dry two tons of leaves every 24 hours.

Pennsylvania and Wisconsin had the best yields. The work continues and the valuable records will be available if ever again the project has to be resumed.

The following summary of yields and assays for the belladonna leaf crops is of interest. It should be borne in mind that the U. S. Pharmacopoeia XIII requires a minimum of 0.3% total alkaloids.

Attempts to grow rhubarb roots (*Rheum officinale* Baillon, *R. palmatum* L.) for laxative use in the United States was disappointing. The plant requires the steady, slow development and growth conditions of central China to produce a large, compact, medicinally effective root and rhizome.

YIELDS AND ASSAYS OF DOMESTIC BELLADONA

STATE	NO. OF FARMERS	AVERAGE YIELD PER ACRE	PERCENTAGE OF TOTAL ALKALOIDS		
			LOWEST ASSAY	HIGHEST ASSAY	AVERAGE ASSAY
New Jersey	1	530 lbs.	.43%	.52%	.47%
Ohio	30	309 "	.47	.48	.475
Pennsylvania	73	787 "	.34	.64	.52
Tennessee	30	162 "	.44	.57	.53
Virginia	26	207 "	.52	.55	.54
Wisconsin	56	970 "	.38	.60	.46

Belladonna was placed in cultivation at an even earlier date, there being no accessible foreign areas where it could be collected in sufficient amount. During the first World War a small quantity was grown in California, but not on a scale or with success comparable to operations during the more recent war. In cooperation with the Bureau of Plant Industry, a quantity of seed was procured. Private negotiations with Switzerland yielded a few more pounds, and in 1941 the first crop was harvested. It was disappointingly poor.

The increasing shortage of juniper berries was taken care of by extensive collections, principally by farmers in the State of Maine. At first the individual lots were small and of uneven quality, and every conceivable type of packing was used, including old pillow slips. A

good bit of sifting and grading had to be done on these early lots. But as the collectors gained experience, the quality soon improved to a point where the finished product compared quite favorably with berries formerly imported from southern Europe.

Arnica flowers (*A. Montana* L.) for treating bruises and sprains presented a somewhat different problem. The European Alps are the usual commercial source. This species of *Arnica* is not found growing in America nor is it a practical crop for cultivation. Research revealed that several species native to the western United States were acceptable in medicine, and some of them were made official in Supplements of the National Formulary VII and in the National Formulary VIII, namely, *A. fulgens* Pursh, *A. sororia* Greene and *A. cordifolia* Hooker. These species grow quite profusely in the alpine meadows of the Rocky Mountains, especially in Colorado. Domestic collection was initiated with success and continues in view of the shortage of acceptable qualities from Europe. Furthermore, the domestic species are not plagued by infestations of *Trypeta arnicivora*. In this and some other respects, such as cleanliness, the American flower is superior to the European item.

On the West Coast several firms in that area produced relatively small but very welcome quantities of agar from the seaweeds (Rhodophyceae) of southern California and the Pacific coast of Mexico. More detailed information on this and related marine products appears in an excellent article in the first issue of Economic Botany.

New Activities in Foreign Areas

In Argentina there were extensive cultivations of many botanicals, formerly obtained from abroad, such as stramonium (*Datura Stramonium* L.), used chiefly to relax the bronchial muscle in bronchial spasms of asthma, chamomile flowers and fennel seed (*Foeniculum vulgare* Miller) used as a stimulant and condiment.

Pyrethrum flowers were obtained in increasing quantities from cultivations in the Belgian Congo and Kenya Colony as the Japanese variety became unavailable. Some smaller quantities of poorer quality were produced in Brazil.

Peru was the source of many tons of cube roots (*Lonchocarpus Nicou* DC.), a source of the valuable insecticide rotenone formerly obtained in quantity from plants of the genus *Derris* in the East Indies. The necessary ground work was fostered by the United States and Peruvian governments and some private organizations in the United States.

Although constantly threatened by the impending closeness of the Japanese armies, India became an increasingly important source of supply. Rhubarb root from the foothills of the Himalayas did yoeman service until China resumed her shipments not so many months a

The Iberian Peninsula supplied urgent requirements of ergot, gentian root (*Gentiana lutea* L.), juniper berries, and orris root (*Iris florentina* L., *I. germanica* L., *I. pallida* Lamarck).

Before World War II most alkaloids and glucosides were imported from Europe, mostly from Germany and Switzerland, and to some extent from France. Only the opium alkaloids, strychnine, cocaine and the cinchona alkaloids were produced extensively in the United States.

With the coming of hostilities, broadened domestic production soon filled the gaps, and the following important phytochemicals, as well as many lesser known ones, were again available: atropine, homatropine, scopolamine, pilocarpine, emetine, totaquine, ouabain and digitonin.

Cinchona

Cinchona[2] alkaloids have always been of the utmost importance to the health of the civilian populations in tropical and sub-tropical climates, and are even more important to the health and fighting power of any army fighting in these regions. For the Allies this meant the entire Pacific and Asiatic theatres of war except Alaska.

Atabrine, a synthetic febrifuge, is indeed an important and highly valuable drug, but it alone does not offer a complete course of treatment for the malarias. The cinchona alkaloids are still highly valued and necessary in controlling this disease, and it is interesting to note that the common name "Bark", when used alone in the trade, refers to cinchona bark.

Before the recent war's outbreak, attempted cultivation of cinchona gained a measure of success in the Philippines. This good fortune was later to play an important part in providing seed for the experimental plots in Central and South America. Although it would take a good many years to grow a new forest of cinchona trees, nevertheless, the work was continued because of the possibility that the invaders might destroy the plantations in Java and in spite of the likelihood that the conflict might not last long enough to make the project worthwhile.

Meanwhile, totaquine was being developed. Totaquine is a standardized mixture of all the natural alkaloids of certain cinchona barks of Latin America origin. This product underwent an extensive laboratory and clinical investigation in 1930 and 1931. In 1931 the Malaria Commission of the League of Nations recommended the use of a standardized preparation of it, and in 1932 the product was recognized in the British Pharmacopoeia. By 1940, when supplies of cinchona bark from the Indies were cut off, totaquine was well established and had been produced since the previous year. All the bark imported from South and Central America, and the finished products, were subject to strict import control and allocation by our Government.

Several South American barks, other than those already noted, were also developed and found to be useful in the production of certain individual alkaloids as well as of totaquine derived up to that time from *C. succirubra*, *C. Ledgeriana* and *C. Calisaya*. These new sources included, in particular, *C. pitayensis*, *C. pubescens*, *Remijia pedunculata* and *Ladenbergia hookeriana*. The Foreign Economic Administration in cooperation with the industry and the governments of the Latin American countries were successful in developing these new sources.

At first, totaquine was to some degree nauseating because the amorphous quinoidine in it was not removed. Today, totaquine contains the four desirable alkaloids—quinine, quinidine, cinchonine, cinchonidine—with a medicinally inactive adjusting agent and can be considered, in every way, the therapeutic equivalent of quinine sulfate. All through the war, supplies were tight, but without totaquine the casualty lists would certainly have been more depressing.

Other War Time Difficulties

The passage of two wars has gradually changed the routing of foreign drugs through the trading centers of the world. Formerly these items were obtained to a considerable extent from the markets in London, Hamburg and Rotterdam. But now the United States obtains practically all of its supplies direct from the

[2] Cinchona bark is derived from *Cinchona succirubra* Pavon et Klotzsch, *C. Ledgeriana* (Howard) Moens et Trimen, *C. Calisaya* Weddell, and hybrids of these species and hybrids of these with other species of *Cinchona*.

various scattered origins. This was an inevitable and desirable outcome.

As for the primary sources of supply, the two wars had little effect in permanently changing them or replacing them. For Rhubarb Root we still look to China; for Black Pepper (*Piper nigrum* L.) we still rely on the Indies and India; Eastern Europe still supplies the best Valerian Root (*Valeriana officinalis* L.), and the best AgarAgar (*Gelidium* sp.), in quantity, will still be produced in Japan and Korea. A long list of examples could be given and there would be few exceptions to the generality.

The reasons for this condition are many, but to mention a few: It is no small matter to naturalize a species in a strange habitat, nor is there sufficient economic incentive to do so, in most instances, during times of peace. Not many drug crops lend themselves to successful cultivation. Only certain species of plants are acceptable in medicine, and most related species, however abundant elsewhere, are not acceptable or established.

It is appropriate to mention here another difficulty encountered when a replacement for a standard item is to be introduced, assuming that it is not radically different. Consider, for a moment, Black Pepper. This established item was famously scarce during the war. There are other reasonably abundant pungent species of *Piper* available in western Africa, but the housewife would display the same sales resistance to this new introduction as she did towards Brazilian maté when tea was becoming scarce. And if it be a drug, once the many months of preliminary work has been done, the physician must be introduced to it, educated in its varying manner of use and convinced of its value.

One must have a "Blue Ribbon Winner" before attempting to enter either of these last mentioned two contests. This is said with all due respect to both classes of persons mentioned.

Numerous examples of this situation occurred during the war. *Gentiana hederiana*, for example, is indigenous to the Peruvian and Chilean Andes, growing in remote areas, and it might possibly be acceptable as a replacement for European Gentian. But before it could be entered into commerce as such, considerable research would have to be done respecting its identification, availability, standardization, medicinal action and a few other factors. Experience shows this procedure to have been unrewarding except in a few selected instances.

In World War II the only successful substitutions were the temporary replacements of Chinese Rhubarb Root and European Valerian Root with the Indian species. In each case the replacing species was judged acceptable for the duration of the war only, and was listed in the National Formulary VII as such.

Aconite Root (*Aconitum Napellus* L.) was another scarce item during the war. The proper species is obtained from the central European Alps, and to a lesser extent from the Pyrenees. In former years rather extensive investigations have been made of the Japanese, Chinese and Indian aconites; most of these either were practically worthless in medicine or were possessed of markedly different and unacceptable activities. Therefore, what little root came from Spain during the war had to suffice. Every possible lead was followed up, with this and with other items, in the hope that a new source of an accepted species might be uncovered. Gratifying results were obtained only infrequently, but all the effort can still be considered as well spent.

A stubborn combination of economic and ecological factors is constantly present in replacing long acepted sources of drugs. They are seldom insurmountable, but frequently give rise only to some highly impractical solutions. An acceptable secondary area for the nat-

uralization of any plant species should fulfill the following requirements, in relation to the primary area, with a reasonable degree of acceptability, and this is quite a list to meet:

1. Geographically opposite in location on globe, season of growth and season of drastic climatic disturbances.
2. Similar climate.
3. Similar soil.
4. Low agricultural wage scale.
5. Geo-political stability.
6. Accessible transportation.

It might be interesting to note that drug collecting is a part-time seasonal activity of rural peoples. If a Tennessee mountaineer can get a high steady wage in a war-plant, such as Oak Ridge, there remains little incentive to collect Black Haw Bark (*Viburnum prunifolium* L., *V. rufidulum* Raf.). If a native of Aruba can earn an attractive salary as an unskilled laborer in the near-by oil refineries, why should he work in the fields producing Aloes (*Aloe Vera* L.) at a smaller figure? And so on throughout the world.

Ephedra (*Ephedra* sp.) is another interesting subject. This herb from China was long the crude source of ephedrine, but its alkaloid was also synthesized on an economical basis before the war. Now that supplies of the crude are again available, their prices have advanced about 300%. There is a body of opinion that synthetic ephedrine is inferior in efficacy to the mixed natural alkaloids, but the synthetic is now more widely employed.

Only a few medicinally active plant constituents have been synthesized economically, the usual low price of crude material being one reason, the technical difficulties of the synthesis the other main one. Crude drugs, however primitive they may appear beside a pure crystalline organic compound, will long occupy an important place in medicine. Indeed, some items which were for several years relegated to a dusty shelf are regaining popularity and value in both old and new fields of medicine. Every day new leads are obtained which point to the probable medicinal value of many plants, and botanical explorations are constantly turning up some new species of considerable value.

The author wishes to express his appreciation of the kindness of George M. Hocking, Ph.D., Professor of Pharmacognosy, University of Buffalo, in reading this paper.

Utilization Abstracts

Naranjilla. In Quito and Guayaquil, especially, but also elsewhere in Ecuador, the juice of naranjilla fruit, *Solanum quitoense*, constitutes a favorite foamy beverage, or "sorbete", nutritiously rich in vitamins, albumin, pepsin, lime, magnesium and phosphate. The spherical fruits, two inches in diameter, are tomato-like in growth, skin texture and internal structure, but are smaller, orange colored externally, greenish orange internally, and pubescent. In addition to being the source of an expressed beverage in Ecuador the fruits are also eaten raw or made into marmalade, pie or other culinary items.

Loss of flavor through pasteurization and addition of antifermentants in canning processes has so far hindered successful commercial export of the juice.

The naranjilla plant, a coarse succulent herb up to eight feet tall with leaves two feet long, is native to Ecuador, thriving best at elevations of 4,000 to 7,000 feet. It is also cultivated in Ecuador, as well as in southern Colombia where it is known as "lulu"; but in Peru the fruit seems to be unknown. The plants flower and fruit continuously, and thus are a continuous crop where cultivated.

Unsuccessful attempts have been made to produce the fruits in subtropical California and Florida. (*W. H. Hodge, Jour. N. Y. Botanical Garden 48: 155. 1947*).

Citrus Products—*A Quarter Century of Amazing Progress*

Highly specialized factories affiliated with the California Fruit Growers Exchange, an orange-, lemon- and grapefruit-marketing cooperative of 14,500 California and Arizona growers, produce tremendous quantities of citrus products which find uses not only in foods but in fields as diverse as medicine and the oil and rubber industries.

GLENN H. JOSEPH

California Fruit Growers Exchange, Corona, California

Introduction

The citrus-products industry—a costly infant in the early 20's—has grown during the past quarter century to one of the world's outstanding examples of successful commercial utilization of an agricultural surplus. Wisdom in planning with confidence, foresight and patience in research and development, converted a botanical wastage to a national industry doing an annual business of more than $125,000,000. Students of economic botany may well pause to review this example of chemurgy as an illustration of the possibilities in their respective phases of this field.

One of the factors which stimulated products development in the citrus industry was the tremendous increase in fresh fruit production during the past two decades. The total citrus production in the United States, in terms of standard packed boxes of fruit, was:

56,000,000 boxes in 1926
93,000,000 boxes in 1936
196,000,000 boxes in 1946

This figure for the 1946 production may be visualized more easily by realizing that 196,000,000 boxes of fruit, stacked end on end, would extend upward 81,000 miles, one-third the distance to the moon! Although continual and extensive advertising campaigns have steadily increased the consumption of the fresh fruit, it has been necessary to utilize an increasing volume of fruit for products in order to give the industry a semblance of stability.

The manufacturing technic by which products of commercial value are prepared from citrus fruit, and in fact the variety of products made, differ widely among the several products factories in the different citrus areas of the United States. The present discussion, however, reflects more or less the citrus-products industry affiliated with the California Fruit Growers Exchange, an orange-, lemon- and grapefruit-marketing cooperative of 14,500 California and Arizona growers. The variety and inter-relation of products which are now manufactured by the factories affiliated with this Sunkist organization are shown in Fig. 1. Fig. 2 illustrates the location in the fruit of several important constituents and also points out the areas designated by the terms "flavedo" and "albedo".

Although citrus fruits include oranges, lemons, grapefruit, the mandarin or tangerine, lime, citron, kumquat and many other varieties, only the first three of this list will be included in the present dis-

cussion, because they are the only ones now of commercial significance in the California citrus-products industry.

Juice Products

Utilization of citrus juices for food purposes has not been a recent development. History reveals that more than 40 centuries ago "oranges and pummeloes" were presented as delicate gifts to a Chinese emperor. Records show that citrus fruits were known to the Pharaohs of Egypt in the 15th century B.C. During the centuries since that time many historical entries show the growing realization that the juices of citrus fruits possess healthful and even medicinal properties. The present generation, however, has been the first to attempt the preservation of citrus juices on a commercial scale.

Fig. 1 shows that juices are obtained by two general methods, crushing or pressing of the whole fruit and burring or pressing the juice from cut halves of the fruit. The juices produced by these two methods differ mainly in regard to the peel constituents which they contain. When whole fruit is crushed the juice usually contains a large portion of the essential oil from the outer rind or flavedo, and of course other peel constituents which are not removed when the juice is subjected to high speed centrifugal treatment for recovering most of the essential oil. These peel materials are responsible for certain flavor differences in the various types of juice. When juice is to be canned or frozen, at natural strength, the fruit is usually burred or pressed so as to avoid the peel materials and possible oil flavors which

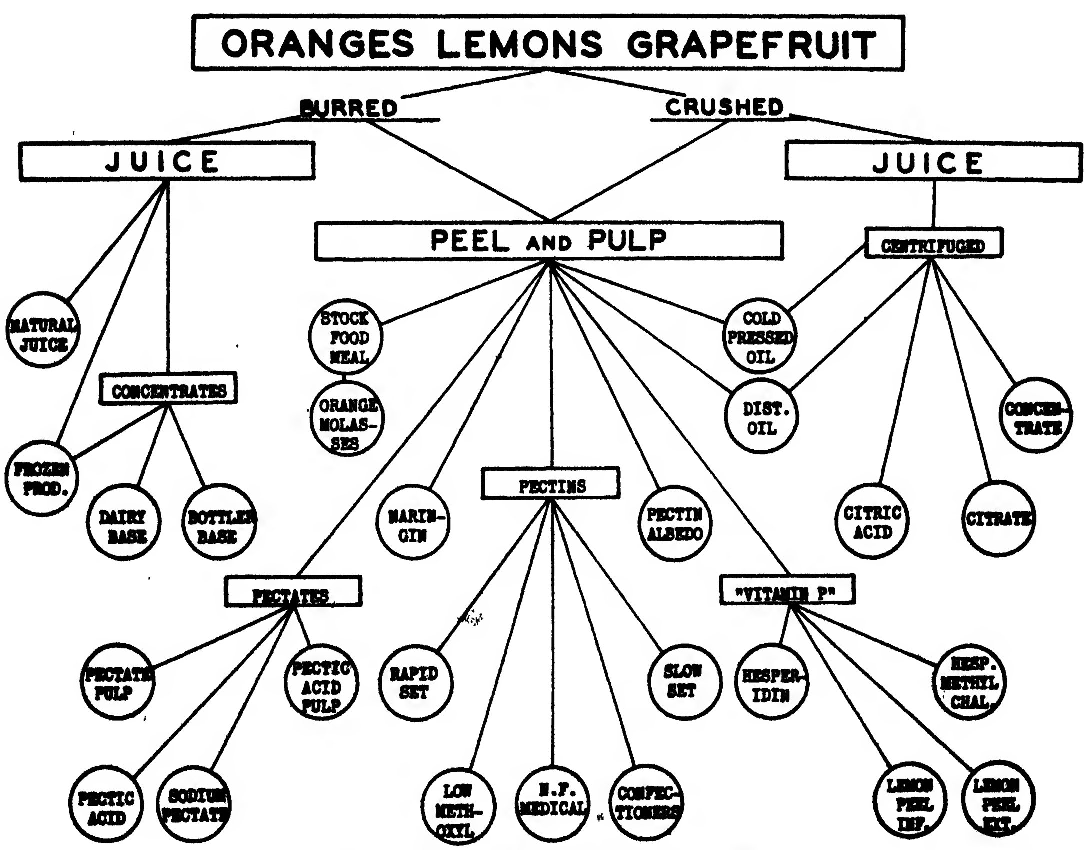

FIG. 1. Chart of citrus fruit products.

they may impart. Although much juice is still prepared by hand-burring or reaming of cut fruit, there are several mechanical methods available for preparing excellent burred juice.

Citrus juices contain pectic enzymes which act upon the small amount of pectin usually present and cause it to flocculate and carry down the fine suspended solids characteristic of freshly prepared juice. This self-clarification and subsequent sediment formation in packaged juices may be avoided by using a patented process of "flash pasteurization" developed in the Exchange laboratories. This process also permits maximum flavor retention.

A considerable percentage of the various citrus juices goes into concentrated and blended products designed to meet the varied requirements of the beverage industry. Concentration of the juices is usually accomplished by utilizing stainless steel vacuum pans where water removal is possible without appreciable temperature rise. The essential oils, sometimes desirable for maintaining the true flavor of the particular fruit and which may have been removed by the concentration process, are usually added after concentration or are supplied in an extract or emulsion form with the concentrated juice, to be added when the juice is mixed with sugar sirup prior to final bottling as a beverage.

The juice from crushed fruit is usually passed through high speed centrifugal separators in order to remove the essential oil introduced from the peel. The resultant juices are frequently vacuum concentrated for use in certain blends where their flavor is desirable.

The successful production of citrus juices for world wide distribution has been made possible by years of careful research and is continuing only through diligent efforts by specialized bacteriologists, chemists, engineers and a wide range of other technical personnel. There are many, many physical and chemical factors which are involved with the extraction and preservation of such delicately flavored juices as those from citrus fruit. Research on the subject of citrus juices is today concerned not only with processing technics but goes back to cultural practices, picking and handling methods, and even to transportation factors. Investments in research and development have indeed been extensive.

These efforts have made possible the development of this phase of the products industry to the point that the production of canned natural strength citrus juices in the United States has reached an annual volume in excess of 60,000,000 cases (24 No. 2 cans per case). The annual volume of concentrated citrus juices in this country is usually about 1,000,000 gallons, although during the recent war period this figure was in excess of 3,500,000 gallons, due mainly to lend-lease purchases for fortifying the diets of children and expectant mothers.

Essential Oils of Citrus

The outer layer of the rind, or the flavedo, of citrus fruits contains the essential oils which are so widely used in the food industries as flavors. Fig. 1 shows that two types of oil are listed, cold pressed and distilled. The cold pressed type is the more important and is the only one admitted by the United States Pharmacopoeia. This type, from oranges, is listed in the U. S. P. XII under the heading "Oleum Aurantii", where the description is: "Oil of Orange is the volatile oil obtained by expression from the fresh peel of the ripe fruit of *Citrus Aurantium* Linné var. *sinensis* Linné (Fam. Rutaceae)". The corresponding oil from lemons is described in the U. S. P. XII, under "Oleum Limonis", as "Oil of Lemon is the volatile oil obtained by expression, without the aid of heat, from the fresh peel of the fruit of *Citrus Medica* Linné var.

FIG. 2. (*Upper*) The parts of an orange and a lemon from which citrus products are obtained. FIG. 3. (*Lower*) One of the pulp drying units in Exchange Factories. (*Courtesy California Fruit Growers Exchange.*)

Limon Linné (Fam. Rutaceae), with or without the previous separation of the pulp and the peel". No corresponding definition for grapefruit oil has yet been made official.

The cold pressed oils, although actually existing in the peel, are usually obtained commercially from the juice into which they have been introduced during pressing of the whole fruit. The juices are passed through supercentrifuges in order to throw out the oil. There are certain mechanical means of expressing the juice of oranges and at the same time collecting the expressed oil during the same operation, without the aid of a centrifuge. It is for these reasons that cold pressed oils are shown in Fig. 1 as arising from both the juice and from the peel.

This same reason applies to the position occupied by distilled oils in the chart. The pressing and centrifuging methods are not quantitative in their removal of oil, and consequently some further amounts of oil may be obtained by steam distillation of the pressed fruit. The oils prepared by such a method are quite different in character from those made by cold pressing. Although the distilled oils may be used as flavor in certain food products, perhaps the greatest application of these oils is in the field of perfumes, as in soap manufacture.

The processes by which the cold pressed oils are handled so as to give them great clarity and stability are too complex to be treated here. The U. S. P. standards for these oils are quite rigid and require the utmost care in manufacture and considerable analytical work in laboratories to insure compliance with them. These oils are used in the food industries wherever the flavor of the particular citrus fruit is desired. The confectionery and baking industries are users of large volumes of orange and lemon oil. Household flavoring extracts, of course, also utilize these oils.

Citric Acid

The chart of products previously referred to shows citric acid and citrates as being derived from the juices of three varieties of fruit. Although it is true that citric acid is the main acidic material in the juices of fruits from all varieties of citrus, the amounts present in varieties other than the lemon and lime are too small to justify extraction with the present commercial methods. The juice of the lemon contains 5%–7% citric acid, about five times as much as is present in orange juice.

The methods in use today for preparing citric acid from lemon juice follow the same chemical pattern first used by Scheele more than 150 years ago. The juice after being subjected to about a week of spontaneous fermentation which permits easier and better later filtration, is heated to the boiling temperature and filtered sparkling clear. Sufficient calcium hydroxide suspension is added to the boiling hot juice to precipitate the citric acid as the salt, calcium citrate. The calcium citrate is later suspended in water and decomposed by the proper addition of sulfuric acid to give the insoluble calcium sulfate in a solution of citric acid. Ordinary filtration removes the calcium sulfate, and then citric acid may be crystallized from the filtrate and purified by any of several commercial processes.

Chemical control is necessary over all the steps in citric acid manufacture. The U. S. P. specifies that the product contain not less than 99.7% of pure citric acid in monohydrate form, and, further, limits the heavy metal impurities to not more than five parts per million. The principal salt of this acid is sodium citrate. Millions of pounds of the white crystalline acid and its various salts are used annually in this country in the food and pharmaceutical industries.

Pectin

Pectin is defined by the National Formulary, Eighth Edition (1946), page 374, as follows: "Pectin is a purified carbohydrate product obtained from the dilute acid extract of the inner portion of the rind of citrus fruits or from apple pomace. It consists chiefly of partially methoxylated polygalacturonic acids".

Pectic substances, although available since the creation of plant life on this planet, have been an article of human diet only since Adam and Eve began eating apples. Actual scientific publications describing the pectic substances did not appear, however, until the beginning of the 19th century. Pharmaceutical and medical applications of pectin were first mentioned in the literature in 1825. During the time since 1825 the scientific literature on the pectic substances has grown to voluminous dimensions, and the substances themselves have found many commercial uses, not only in foods and pharmaceuticals, but in industries as diverse as steel, rubber, paper and oil.

Botanists and plant physiologists commonly refer to pectin as the intercellular cementing material in the middle lamella and primary cell walls. Some investigators believe that pectin or its precursors coat the macro-mols of cellulose fibers. Recent physico-chemical studies indicate that the cellulose fibers are held together by intramolecular forces and that pectin and protopectin (the immediate precursor of pectin) form a chain-like network of intercellular material meshing in with the cellulose structure.

The pectic materials develop under conditions of rapid growth and high water content, and consequently they are present in large concentrations in fruits and stalks of fast growing plants and in the spring wood of trees. During ripening of fruits the pectin content steadily increases and reaches a maximum at maturity, then hydrolysis takes place. Enzymic hydrolysis converts the water-insoluble protopectin to the water-soluble pectin, and then on to the hydrolyzed and depolymerized pectates, and no doubt eventually to sugars. At all times the sum of the protopectin, pectin and pectates is probably a constant. At no one time, however, in this progressive change is there any considerable amount of water-soluble pectin. Pectin is responsible for turgidity of the cellular structure. After maturity, when enzymic hydrolysis has occurred, the structure weakens and complete dissolution of the framework takes place.

Although pectin is widely distributed in the plant kingdom, there are only a few sources at present capable of commercial utilization. These are in citrus peel and in apple pomace. Fig. 2 shows the location of protopectin and pectin in citrus fruits—in the white inner rind or albedo. The albedo contains about one-half of its weight in pectin, on the dried basis, although extracting processes capable of producing pectin with a high gel-forming ability fail to obtain a yield of any such magnitude. Since most uses for pectin are dependent upon its ability to give viscous sols and gels under certain conditions, and since these properties are enhanced by the highly polymerized state of the pectin molecular aggregate, the extraction process must be gentle. The pectic raw material is usually treated with a warm dilute acid to convert the protopectin to pectin, and then filtration separates the pectin solution from the cellulosic material of the fruit source.

Pectin may be precipitated from its water solutions by addition of an alcohol or by use of a polyvalent metallic ion, such as is furnished by aluminum sulfate or chloride. Both these processes are in use today for the preparation of citrus pectin. The final pectin product

made by either process is a nearly white powder with a mucilagenous taste and no odor. The production of dry pectin in the Exchange factories amounts to many thousands of pounds each month, and additional factory facilities for making pectin are under construction.

The chart of products lists the five most commonly known types of pectin made in the Exchange factories. These types may be made from either of the citrus varieties listed.

The most important pectins in the food field are the two types known as rapid and slow set varieties, used in jam and jelly-making. This designation refers to the time required, after all the ingredients have been added in the correct proportion, for a jelly to "set" or begin to show evidence of gel formation. Makers of berry jams prefer to have their product "set" soon after filling into containers, while still at temperatures above the sterilization point, so that the berries do not float to the top and leave a layer of clear jelly in the lower part of the container. This requires a "rapid set" pectin or what is sometimes designated as a "jam pectin".

Commercial jelly makers usually arrange to have their products remain fluid until the containers are filled, washed, labeled, packed into cartons and stacked. This requirement can be met by using a "slow set" or jelly pectin. Manipulation of the pectin molecular shape and size during manufacture is the means by which the setting characteristics of the pectins are altered.

Confectioners pectin became an article of commerce about 15 years ago, and with it came a "gum drop" of new and superior qualities. Up to that time various jelly and gum pieces had been made by using gelatin, starch, gum arabic or agar-agar and by combinations of these materials. Candies made from these materials had only a short shelf-life and were far from ideal in regard to flavor, texture and ease of manufacture.

A special type of citrus pectin was developed for use in confectionery where jelly pieces of excellent texture, flavor and stability were desired. This pectin

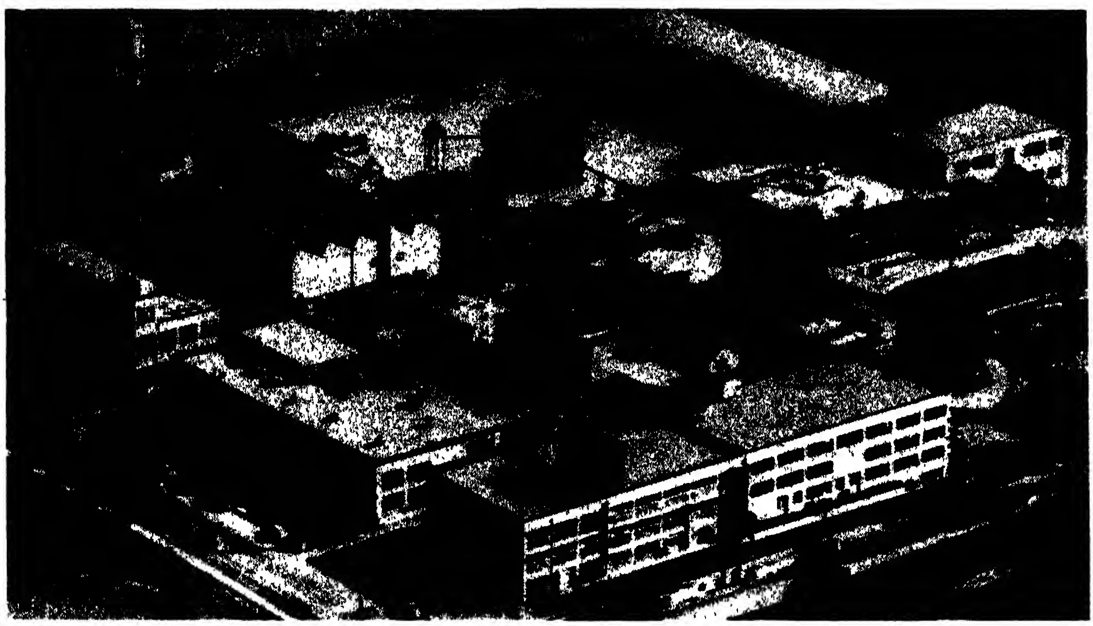

FIG. 4. The Exchange Orange Products Co., Ontario, Cal.

was quite slow setting so that even when the batches were cooked to a sugar content of 75%–80% and were properly acidified, the finished batch could be transferred by pipelines in the factory to automatic depositing or molding machines without danger of pre-setting. Many millions of pounds of "gum drops" and high quality jelly centers are made today from this special type of pectin which resulted from several years of chemical research and development.

Low methoxyl pectins are just beginning to enter the field of commercially valuable citrus products. The jelly, jam and confectionery pectins just mentioned, contain about 9%–11% of methoxyl groups, $-OCH_3$. All these pectins require more than 60% sugar for suitable final gelation. They are high methoxyl pectins, or strictly speaking, high-ester pectinates. During the past six or eight years it has been found that by removing some of the methyl ester groups from pectin there could be obtained a product which would form a gel even if the sugar were omitted, provided, however, that sufficient calcium or other similar metal were present.

These low methoxyl pectins are suitable for use in salads and desserts where sugar solids may be less than is required for the usual pectin gels. The gels formed by these new pectins result from a structure of pectinate molecular aggregates tied together by divalent ions such as calcium, and are not dependent upon any certain sugar content. Removal of the ester groups from pectins may be accomplished by using enzymes or a carefully controlled acid or alkaline treatment, or by combinations of these methods. The low methoxyl pectins are finding applications in the production of fruit salads and puddings, fruit mixes for ice cream making, fountain sirups, gels for diabetics, milk puddings, and in frozen berries and tree fruits.

Medical uses for pectin were first mentioned by Braconnot in 1825, but it was not until 100 years later that pectin actually received attention in the medical journals. The use of pectin in the treatment of colitis, diarrhea and bacillary dysenteries grew out of the use of the apple diet which developed in Europe during the years following 1928 when the Heisler-Moro diet first became popular. Medical investigators in various countries soon concluded that the beneficial properties of the apple diet were due to the pectin of the apples. Soon the extracted pectin was used instead of the whole apple. At the present time many pharmaceutical products used for these intestinal diseases contain a purified pectin made to conform to the rigid standards of the National Formulary.

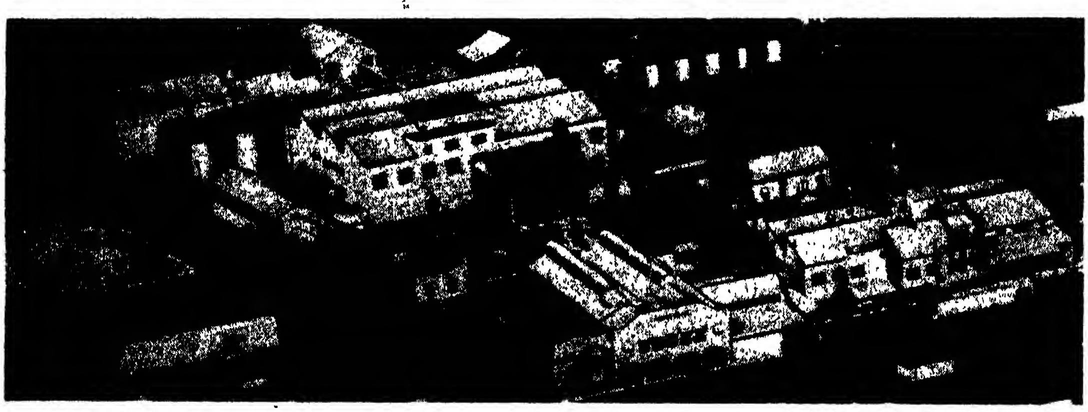

FIG. 5. The Exchange Lemon Products Co., Corona, Cal.

Hemostatic effects of pectin solutions were first reported in medical journals in France in 1924. Since that time

many hundreds of cases have been reported in the literature, cases in which pectin had been introduced intramuscularly or intravenously and produced a distinct accelerating effect on the coagulation of drawn blood. When pectin solutions in similar amounts are added outside the body to previously drawn blood, there is apparently no particular coagulating effect, and when pectin is added parenterally there is no coagulating effect upon the circulating blood.

During the recent world war much success attended clinical uses of properly prepared pectin sols for the transfusion treatment of shock, using the pectin sols as substitutes for human plasma. This particular application for pectin has not yet reached widespread recognition because human blood and plasma became so plentiful through volunteer donations that the emergency substitute was not needed. Extensive biological and clinical studies did show, however, that no undesirable effects resulted from the intravenous use of properly prepared pectin sols when used even in quantities substantially above the normally required dosage.

These intravenous uses for pectin made it necessary to maintain strict control of pectin quality and to produce as nearly a pure pectin as chemical research indicated was possible. The National Formulary (Seventh Edition and the new Eighth Edition) contains a monograph on and the specifications for such a product under the designation of Pectin N. F. The present medical uses for this high quality pectin, in addition to those already mentioned, extend to the preparation of pastes or salves, emulsions, tablets, powders and suspensions, for external and oral administration.

The Pectates and Stock Food Meal

The two materials classed as pectates in Fig. 1, which are the peel products of most interest from the viewpoint of the large scale utilization of surplus citrus fruit, are the "Pectate Pulp" and "Pectic Acid Pulp". These products, contrasted with those listed under pectins, are not highly refined and are sold by the ton rather than by the pound.

Citrus pulp includes the peel, after the oil has been removed from the flavedo, and the cellulosic structure remaining after the juice has been pressed or burred from the edible portion of the fruit. Disposal of a thousand or so tons of this material each day becomes a problem of major importance to factories attempting to recover salable products of citrus at reasonable cost figures. Early attempts at drying the pulp, which is not needed for pectin production, using ordinary large-scale drying equipment, met with failure.

Continued chemical research, however, developed pulp-treating processes which permitted the successful and economical drying of pulp in huge rotary driers, as illustrated in Fig. 3. The pulp so dried is being used as a stock food, especially in mixed feeds. Part of the liquors which result from the treating steps in making orange meal are further treated to produce a molasses-like material which is sold for use in connection with alcoholic fermentation processes and for certain stock food mixtures.

Pectate pulp and pectic acid pulp are additional products which are made in the same drying equipment as used for the stock feeds. When the citrus pulp is treated with an alkali the pectin is converted to a pectate and the natural calcium of the pulp reacts with the soluble pectate to produce water-insoluble calcium pectate in the cellulose matrix of the pulp. This dried pectate pulp, in a coarsely ground form, becomes dispersible in hot water when suitable amounts of added soda ash and a phosphate are present. These dispersions have been used for certain types of steel quenching, for aiding latex

creaming at rubber plantations, as an ingredient in oil-well drilling muds, for paper sizing, and as an antistick on paper containers for asphalt.

The pectic acid pulp is useful for the same general applications and differs from pectate pulp only in that dispersions may be made easily by merely adding any soluble alkali such as soda ash or ammonia. Slight alterations in the manufacturing processes permit production of these pulps with either high or low viscosity.

Pectic acid is a refined material separated from the pulp. It is insoluble in water but reacts readily with alkalis to give pectates. It is used as an acidulant in certain pharmaceutical powder mixtures, especially in effervescent mixtures where moisture absorption on storage in humid climates previously caused premature reaction between the ingredients and loss of effervescent ability. The only salt of pectic acid now of much importance is sodium pectate.

"Pectin-Albedo"

This term, originally coined to be descriptive of the product made by a specially perfected process, has grown to be recognized in the pharmaceutical and medical fields. The discussion above, under the heading "The Pectins," told how, in the peel of fruit, the water-insoluble protopectin is converted by natural enzymic processes to the soluble pectin and ultimately to depolymerized end-products. The patented process by which "pectin-albedo" is made consists of treating disintegrated peel with a mineral acid in alcoholic solution so as to hydrolyze the protopectin to soluble pectin but, due to the alcohol, keeping the pectin in its original cellulosic environment. This acid-alcohol treatment also removes colors and other soluble components of the peel, so that finally when the peel is alcohol-washed to free it of the acid and is later vacuum dried, there remains only relatively pure cellulose and easily water-soluble pectin.

"Pectin-albedo" is usually further treated by special rolling equipment to produce extremely thin flakes in which the cellulose units are all disrupted and the product can be added to water and taken orally for the treatment of certain intestinal diseases.

Flavanone Glycosides

Fig. 1 lists "Naringin" in one place and then shows four other materials grouped under the heading of "Vitamin P". This was done mainly because of the current interest in the so-called "Vitamin P" substances and because most investigators at the present time do not believe naringin has "Vitamin P" characteristics, even though it is a citrus flavanone glycoside.

The flavanone glycosides of citrus belong to the important and widely distributed group of plant pigments known as the flavones and are somewhat similar in chemical structure to the anthocyanins which are responsible for most of the blue, purple, violet and red shades in plants.

Studies on scurvy more than a century ago demonstrated that lemon juice corrected all the symptoms associated with the disease, including the capillary hemorrhages. Investigations during later years indicated that the vitamin C of lemon juice is the curative factor. When synthetic vitamin C became available, however, it was found to be ineffective in alleviating all the scorbutic symptoms related to capillary weakness. This led Szent-Györgyi and his associates to seek for a substance in lemon which had an activity and importance similar to vitamin C. The flavanone glycosides of lemon were isolated as a result and were termed "Vitamin P" (for permeability factor) in 1936 by Szent-Györgyi.

Therapeutic effects have been achieved

with the "Vitamin P" materials in a wide variety of cases associated with vascular permeability (or capillary fragility) such as:

Vascular Purpura
Psoriasis
Increased Capillary Fragility in Hypertension
Hemorrhagic
Telangiectasia
Retinitis
Measles
Nephritis
Capillary Toxicosis (particularly due to anti-syphilitic therapy)

Many flavanol and flavanone glycosides from a variety of plant sources have been discussed in the literature in connection with their relation to Szent-Györgyi's "Vitamin P" and their use in treating pathological conditions connected with capillary fragility and permeability. Some of these substances are: hesperidin; eriodictyol; quercitrin; rutin; epicatechin; hesperidin, methylated chalcone; and lemon peel infusion, dried.

Hesperidin is the oldest commercially available "Vitamin P" material. It may be prepared from either orange or lemon and is a grayish-yellow, non-hygroscopic powder, relatively insoluble in water and easily made into tablets.

"Hesperidin, Methylated Chalcone" is the name applied to the product obtained by methylation of hesperidin in alkaline solution where the pyrone ring structure opens and the material becomes soluble. It is a yellow, water-soluble powder which is proving to be a valuable member of the so-called "Vitamin P" group.

An aqueous extract of lemon peel, prepared so as to eliminate the pectins and the oils, then vacuum concentrated and dried, is being used under the name of "Lemon Peel Infusion, Dried". When lemon peel is extracted with alcohol and the extract is dried to a pilular mass the material is designated as "Lemon Peel Extract, Dried". It contains the same therapeutic principles as the infusion, and in addition has certain more desirable physical properties.

Naringin is a flavanone glycoside extracted from grapefruit peel and is used commercially for its extremely bitter taste. It has no known therapeutic properties. It has been used in Europe for imparting a desirable bitterness in beverages and in marmalade made from sweet oranges. One of the old household remedies for the common cold was to drink an infusion of grapefruit peel. No doubt the bitterness of the concoction imparted the belief that quinine was present, and perhaps some beneficial results may have been obtained from the vitamins known to be in citrus peel and from the increased fluid intake.

Concluding Remarks

This listing and brief description of citrus products has been presented to bring out the extent to which a group of agricultural producers has gone in order to preserve itself in this generation of economic perplexities. The difficult raw-material problems which beset the factories making the dozens of different products listed above can not be visualized by operators of the ordinary food and chemical factories. The fruit used as a raw-material differs continually, not only in degrees of maturity and in seasonal and varietal respects, but also as a result of locality and soil variations. Another difficult manufacturing problem arises from the fact that the quantity of fruit available for converting into products varies suddenly and from reasons which can not always be foreseen. It is not a matter of knowing what can be sold as products and then obtaining the needed raw-material; it is rather an obligation to take *all* the fruit available from the packing houses when and if they desire to have it converted to products.

Dozens of trained chemists, bacteriolo-

gists and engineers, working not only in expensive and well equipped laboratories, but in key positions throughout management and the factories, are essential to the products manufacturing operations, such as are being successfully conducted by the California and Arizona citrus growers.

Utilization Abstracts

Tropical Plants as Sources of Pectin. Nearly all commercial pectin is obtained today "as a byproduct of the citrus juice and apple cider industries. In the former, pectin is extracted from the peel of the citrus fruit and in the latter it is recovered from the apple pomace, the residue of the cider presses". Industrially pectin is used as a jellying agent in fruit juices and pulps to produce jellies and jams, "as an inert carrying agent for many pharmaceutical preparations, as a sizing agent in the textile industry, as a protective agent in the baking industry, as a creaming agent in the rubber industry, and as an emulsifying agent for many products".

In an effort to find other sources of pectin the Hawaii Agricultural Experiment Station has investigated a number of tropical and subtropical fruits, and has found that common guava (*Psidium Guajava*), papaya (*Carica papaya*), soursop (*Annona muricata*), tamarind (*Tamarindus indica*) and pomelo (*Citrus maxima*) have high pectin content, ranging from .80% to 2.07% of fresh weight, but not enough for commercial development.

The 12- to 18-inch long pods of pink shower (*Cassia grandis*), after removal of the beans, were found to have 16.5% pectin, an amount comparable to some of the established sources of pectin. The beans contain a water-soluble gum that may have value as a creaming agent for rubber or in other capacities.

In addition to the fruit of the common guava and the pod of the pink shower as potential sources of industrial pectin, there is also the pulp residue produced in the root starch industry. Large quantities of root starch are used each year as a sizing agent in the textile industry. The starch is mechanically separated by very fine mesh screens from the finely ground roots, and the residual material is subject to extraction. (*G. D. Sherman & Y. Kanshiro, Chemurgic Digest 6(4): 65. 1947*).

Furfural. Furfural is a technologically important substance "produced commercially in large volume by the action of sulfuric acid on oat hulls, but the use of corncobs, cornstalks, cotton stalks, peanut hulls, beet pulp, wheat husks and other waste agricultural products has been investigated. Any substance containing pentosans is a potential source of furfural.

"The discovery of furfural in 1832 was quite by accident, and until the institution of its commercial production in 1921, it remained a laboratory curiosity. Today, as a result of widespread developmental investigation, it is used on a large scale in such diverse applications as petroleum refining, the purification of butadiene for synthetic rubber production, the improvement of wood rosin, the preparation of plastics and resinous bonding materials, and in organic synthesis for the preparation of pharmaceuticals, insecticides, dyes and other products". (*F. L. Austin, Chemurgic Digest 6(9): 145. 1947*).

Lonchocarpus—*A Fish-Poison Insecticide*[1]

The roots of this tropical vine are the source of the valuable insecticide rotenone, non-toxic to humans, and were imported into the United States in 1946 from Brazil and Peru, from both wild and cultivated material, to the extent of more than 11 million pounds.

E. C. HIGBEE
The Johns Hopkins University

Introduction

MANY an observant Amazon traveler has enthusiastically related how Indians of that region stupify fish by polluting small pools and sloughs with toxic plant infusions, including those prepared with roots of certain *Lonchocarpus* species. One of the most charming of these accounts was prepared for the Smithsonian Institution Report of 1930 by the tropical plant explorers Killip and Smith. It details not only the technique of staging a "pesca", or fish-poisoning expedition, but it also conveys the festive spirit with which the drama is enacted by those people who have the primitive's genius for mitigating work by playful diversion. Fish catching with the aid of lonchocarpus roots is an ancient practice, perhaps rivaling in antiquity the comparable use of *Derris* root in Malaya. As intriguing as the fact that primitive men of both tropical America and Asia discovered identical uses for these legumes is the close botanical relationship of the plants themselves. Their remarkable similarity suggests evolution from a common origin, although their native habitats, as we now know them, are separated by half a world of sea and portions of continents.

History

The identity of the pioneers who discovered the insecticidal value of lonchocarpus and derris is as obscure as that of those who found them toxic to fish. One can only speculate on how long derris had been used by Malayan gardeners as an insecticide before 1848 when Oxley wrote in the Journal of the East Indian Archipelago that it was effective against leaf pests on nutmeg trees. Likewise it is anybody's guess how long South American Indians were using lonchocarpus before 1910 when Gerardo Klinge delayed his travels in the Peruvian Valley of Huancayo long enough to verify that it would kill the sheep tick.

In 1902 the Japanese chemist Nagai isolated colorless crystals primarily responsible for the toxicity of derris root. This pure substance, which he named "rotenone", was found subsequently in 1926 to be the principal active ingredient in the root of lonchocarpus as well. Thus the similarity between these two tropical legumes appeared even more striking. As the definite practical value of rotenone-bearing roots became established by laboratory tests of entomologists, insecticide manufacturers in

[1] Much of the material in this paper is taken from the writer's manuscript on Lonchocarpus, Derris and Pyrethrum, prepared for publication by the United States Department of Agriculture and the Pan American Union. This study was made possible by funds provided through the United States Interdepartmental Committee on Scientific and Cultural Cooperation.

Europe and the United States began importing roots from the Far East and the Amazon to compound commercial dusts and sprays. Impetus was added to the demand for these insecticides when it was determined that they are non-poisonous to man and other warm-blooded animals. They can be used effectively against certain pests of truck and canning crops without hazard to the human consumer. Dip solutions are harmless to livestock while lethal to ticks, warbles, lice and fleas. By 1932 the infant rotenone industry was assured a vigorous maturity. Its insecticidal products are now recognized as among the most effective agents for combating the Mexican bean beetle, wooly apple aphid, European corn borer, pea aphid, housefly, mosquito and cockroach. Associated with rotenone, but less toxic, are a number of other active substances collectively known as "rotenoids" which add to the effectiveness of derris and lonchocarpus.

The discovery of the insecticidal value of these two leguminous fish poisons was a challenging clue to botanists in many parts of the world. Libraries were searched for accounts of fish-poison plants; expeditions were organized to canvass fields and forests for all closely related species. Hundreds of specimens were collected from several continents for the scrutiny of entomologists with encouraging though unspectacular results. Numerous other Papilionaceae, including species of *Tephrosia, Pachyrhizus, Mundulea* and *Milletia,* have been found to contain rotenone and rotenoids but not in sufficient quantity to warrant commercial exploitation without modification by geneticists who may eventually breed strains of superior quality. To date, most progress has been made with *Tephrosia virginiana* by Russel, Little and their collaborators of the United States Department of Agriculture and of the Texas Agricultural and Mechanical College, but the years of exploration for rotenone-bearing plants which may equal or surpass the two now in commercial production are by no means concluded.

Prior to the recent war derris-growers in the Far East exceeded the rotenone-root production of Amazon river-bank-dwellers, since the latter hesitated to make large plantings of lonchocarpus so long as they could more easily exploit numerous small reserves originally established for fish poison purposes. Persuaded by root grinders in Belem, the Brazilian state of Pará in 1934 imposed an export embargo on crude root so as to channel all local harvests into the processors' hands. This action likewise restricted planters' enthusiasm in what was once the most important center of lonchocarpus production, since the millers, protected by their new law, held prices they paid to gatherers at a minimum, while export values of their powdered roots soared on an expanding world market.

The Japanese invasion of Far Eastern derris countries deprived the United States of approximately one-half its prewar supply of rotenone-bearing roots; so early in 1942 the incentive of attractive long-time minimum price guarantees was offered to South American lonchocarpus producers in hope they would swing into large scale operations. Peru responded as quickly as could be expected, since the crop requires two and one-half to three years to mature. In December, 1942, Pará revoked its export embargo on cultivated crude roots so that growers could obtain a share of the new incentive prices, but to this day Brazil has not recovered its once preeminent position. In 1946 the United States, which is the world's largest rotenone consumer, imported a record 11,369,322 pounds of crude and powdered roots. Of this amount only 29,764 pounds were derris and the re-

UNITED STATES IMPORTS OF ROTENONE-BEARING ROOTS, CRUDE AND POWDERED, IN 1,000-POUND UNITS

Country of Origin	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946
Lonchocarpus										
Brazil	1,562	1,793	1,101	1,047	1,311	193	1,469	554	94	473
Peru	378	477	1,730	2,225	2,525	2,503	2,079	5,452	8,604	10,862
Other (Western Hemisphere)	.	55	170	74	61		22	321	71	5
Total	1,940	2,325	3,001	3,346	3,897	2,696	3,570	6,327	8,769	11,340
Derris										
British Malaya	402	583	2,326	1,842	1,930	653	.	.		.. ..
Neth. East Indies	57	136	280	997	1,700	430		.	.	.
Philippine Islands	111	23	262	231	377	19		.	2	.. .
Other (Western Hemisphere)		. .	....	.		. .		. .	3	13
Other (East Asia and Africa)	2	2	40	152	93				45	16
Total	572	744	2,908	3,222	4,100	1,102			50	29

mainder lonchocarpus. Peru supplied over 95% of the total. Even these imports were not sufficient to satisfy a potential United States demand estimated at about 25 million pounds of 5% rotenone content from which approximately 125 million pounds of commercial insect powders or their equivalent could be manufactured.

ESTIMATED WORLD PRODUCTION OF ROTENONE-BEARING ROOTS (DERRIS AND LONCHOCARPUS) IN 1,000-POUND UNITS

Country	1938	1939	1940
Brazil	2,500	1,500	1,000
Peru	1,500	2,500	3,000
Venezuela	(1)	200	100
British Malaya	2,000	3,500	3,000
French Indochina	(1)	300	150
Japan	100	650	(2) 2,000
Netherlands East Indies	250	1,500	1,750
Philippine Islands	200	650	900

(1) Not available.

(2) Anticipated production as reported from that area.

Taxonomy

Botanists have not as yet agreed on a scientific name for the Peruvian lonchocarpus which has become so important commercially as the result of an expanding plantation industry in the Amazon headwaters region above Iquitos. Their hesitancy may be attributed, in part, to a lack of flowering and fruiting herbarium collections which would assist toward a satisfactory taxonomic decision. Krukoff and Smith called this plant *L. utilis* after having studied their collections of leaf specimens. Additional field and herbarium research lead Hermann to name it *L. Nicou* var. *utilis*. In his Flora Of Peru, MacBride even classifies it as a form of *Derris*. From a horticultural as well as a commercial viewpoint it is helpful to maintain a generic distinction between the South American and the southeast Asian plants; so it is fortunate that most systematists continue to call it ***Lonchocarpus***, even though they do not agree on a species name.

Rare flowering and even less frequent fruiting are apparently characteristic of the commercially important lonchocarpus species. In 1944 research workers at Tingo María, Peru, induced flowering by girdling branches of two-and-a-half-year-old plants; so, possibly, taxonomists may eventually secure fértile specimens to study. The type specimen of *L. nicou* was collected in French Guiana and was described by Aublet in 1775. Today only leaf fragments remain of that material, and there are apparently no known fertile collections of authentic French Guiana *L. nicou* available to taxonomists.

The only well documented species of commercial lonchocarpus is *L. urucu* which was named by Killip and Smith in 1930 after their explorations in the Brazilian Amazon where they gathered specimens with flowers and legumes. *L. urucu* is the source of most of the roots exported from Brazil. Perhaps until adequate fertile collections are obtained of French Guiana *L. nicou* and of the Peruvian species which Krukoff and Smith call *L. utilis,* the taxonomy of the most important insecticide plant produced in the Western Hemisphere will remain confused.

In its native habitats lonchocarpus is known by various common names, all of which connote its value as a fish poison in the local tongues. In Peru it is referred to in Quechua as "cube" and in Spanish as "barbasco". It is designated as "timbó" in Brazil, "haiari" in British Guiana and "nekoe" in Surinam.

FIGS. 1 & 2. Fruiting and flowering branches, respectively, of *Lonchocarpus urucu.*

Sources of Commercial Supplies

Although plants of the genus *Lonchocarpus* are rather widely distributed throughout the Western Hemisphere, the present commercial rotenone-bearing species are native only to certain trop-

ical rain-forest areas of South America. Previous to 1939 most of the total crude and pulverized root entering world markets was harvested in the Brazilian states of Amazonas and Pará. Since then, however, the quantity grown for export on Peruvian plantations has steadily increased to the current figure. At the present time, judging from the volume of production, approximately 12,000 to 18,000 acres are planted in eastern Peru. By comparison the cultivation of this crop for export has hardly begun in Bolivia, Ecuador, Colombia, Venezuela and the Guianas where rotenone-bearing species are also native. Only slightly more interest has developed in Brazil despite that country's one-time dominance of the market.

The principal production centers in Peru are located near the villages of Lagunas, Yurimaguas and Tingo María on the Huallaga River; Jeberos between the Huallaga and the Marañon Rivers; Contamana on the Ucayali River; Barranca and Nauta on the Marañon; Iquitos and Tamshiyacu on the Amazon; and Satipo on the Satipo which is a tributary of the Tambo river. In Brazil plantings are found near Belem, Portel, Mazagão and Macapá which are close to the mouth of the Amazon; at Porto de Moz on the Xingu; at Belterra on the Tapajoz; and in the environs of several villages along the Amazon, Negro and Madeira rivers in the State of Amazonas. In Venezuela small plantings are reported near El Tigre in the state of Anzoategui and on the Orinoco islands of Urbana and El Infierno on the western border of Bolivar State.

Since the value and technique of cultivating the plant is little known outside of Peru and a few villages in Brazil and Venezuela, many years may pass before lonchocarpus becomes established as a commercial crop in any other tropical country. If it is eventually determined, however, that it has a cultivation range approximating that of derris, it may replace derris to some extent, since, using present cultural methods, it requires less labor to produce equivalent amounts of rotenone.

Field Preparation

Present methods of lonchocarpus culture are those developed through trial and error by Amazon Indians and river-

FIG. 3. Planting lonchocarpus cuttings in eastern Peru.

bank settlers who sought to provide themselves with adequate supplies of fish poison.

Plantations, or barbascales, as they are known in Peru, are often established on what previously has been woodland, since in the rain-forest areas of the Amazon basin it is generally considered an easier and more profitable task to open up new clearings in the forests than to reclaim old cultivated fields from the

weeds and keep them clean. This practice prevails partly because draft animals, moldboard plows and mechanical cultivators are almost unknown, and because it is too difficult to combat the vigorous encroachment of grasses with simple hand tools, such as the hoe and the machete.

When a timbered area is felled and burned over, it may be littered with charred stumps and logs, but for several years the farmer finds comparatively little grass growth competing with his crop. Of course, animal- or tractor-drawn implements could not be used on land cleared in this superficial manner, even if the farmer could afford them.

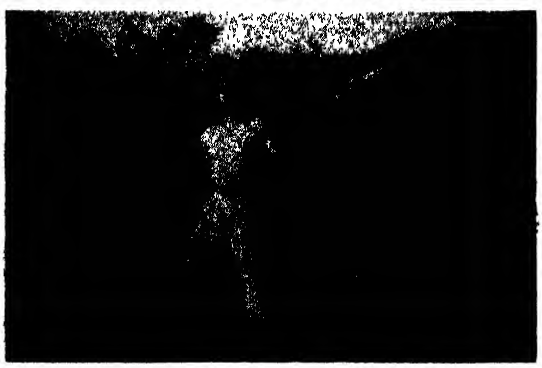

Fig. 4. (*Upper left*). Packing bales of lonchocarpus roots at the Victor Israel Co. warehouse in Iquitos, Peru.

Fig. 5 (*Upper right*). A log-strewn field in eastern Peru ready for planting cuttings.

Fig. 6 (*Lower left*). A plantation of three-year-old lonchocarpus.

Fig. 7. (*Lower right*). The exposed root system of a lonchocarpus plant.

Reduced soil fertility, due to the leaching of certain elements and rapid oxidation of organic matter, also contributes to the planter's decision to abandon lonchocarpus sites to volunteer forest after two or three crops have been grown and to open up new land by clearing woodland areas. Aside from this primitive forest-crop-forest cycle which may be repeated after long intervals and which provides a generous although poorly distributed top dressing of wood ash minerals to the soil, the Amazon axe and machete farmer has not yet developed field crop rotations and manurial treatments which will maintain the productivity of upland soils indefinitely. Some of the soils on which crops are grown under this system of shifting cultivation would not be capable of continuous clean cultivation, even with better treatment. They would rate as submarginal lands that would not have been

cleared had permanent agricultural use been contemplated, but they are fully capable of producing one to several satisfactory crops before they must be abandoned to volunteer bush cover.

Land clearing operations generally take place during the drier months of the year, so that undergrowth and the leaves and branches of fallen trees will have an opportunity to dry out sufficiently to burn. In the Amazon region there is little danger that brush fires will spread beyond the clearings into the green growth of the surrounding rainforest; so on a clear day, when the trash is dry enough and there is relatively little wind, it is set ablaze. The flash burn consumes the mass of debris within a few minutes, but slow smouldering fires ignited in stumps and logs may continue for days or weeks. No further seed bed preparation is practiced by the grower who simply waits until the subsequent rainy season to plant his crops.

Propagating Material and Field Planting

Techniques used to cultivate lonchocarpus resemble those employed by the Amazon native to grow yuca, *Manihot esculenta* Crantz, which is his principal subsistence crop. Both plants are vigorous and will return fair yields, even though cultivated in a rather haphazard manner. For propagating material the planters use leafless stem cuttings 10 to 18 inches in length and from three-quarters to two inches in diameter. The average farmer exercises little care in the preparation of these cuttings which are often needlessly bruised and crushed or even exposed to sun and rain before planting. As a consequence a mortality of 50% or more is not unusual. By observing reasonable precautions, survival can be 80% or more. The cuttings which usually possess from three to six axial buds are set into holes made with digging sticks, hoes or machetes. They are inclined at angles varying from approximately 15° to 60°. The apical portions with one or two buds are left exposed, while the remainder of the cuttings are covered with soil which is firmed around them by the tramping of the planters' feet. One or two cuttings are placed in a single hole, and sometimes two or more holes may be dug side by side. Some planters even dig a series of holes to form such circles, squares, triangles and rectangles. Seldom is a field laid out in rows or check rows, since the tangle of stumps and fallen logs makes precise spacing impossible. Distances between plants and planting designs are not standard. Reports range from three to 12 feet, although five to seven feet seems to be most common. Closer spacing is generally practiced when only one or two cuttings are used at each location and where skips are likely to occur due to poor survival of the cuttings.

Interplanting

The average rural Amazonian is a subsistence farmer and hunter. He grows crops such as yuca, beans, corn, rice, bananas, plantains and okra to assure himself a minimum food reserve. He also gathers a portion of his sustenance from the forest and the rivers. Wild nuts, fruits, roots, palm hearts, fish and game contribute to his diet. He requires a small amount of money to buy tools, clothing, patent medicines, ammunition and other essentials. Lonchocarpus is a cash crop ideally suited to his needs. It requires two and a half to three years to reach maturity, and during the first year while the plants are still small they can be conveniently interplanted with food crops which will not interfere with development of the lonchocarpus. During the second and third years the lonchocarpus grows to a height of six to eight feet, and the plantation broadens into a bushy thicket. At that stage interplanting becomes impractical, although

mats of bananas, plantains and pineapples which have become established are left undisturbed. The average lonchocarpus planter has several small fields at various stages of maturity, and in those which have recently been established he has little difficulty finding room for his subsistence crops.

Weeding

Using hand tools, as is the present custom, the average family raising lonchocarpus cannot maintain more than five to six acres in production at any single time. Experienced growers at Lagunas, Peru, in 1943 informed the writer that a hectare, or 2.4 acres, of two-and-a-half to three-year-old plants on virgin land, which will normally yield about 10,000 pounds of green root or 5,000 pounds of air dry root, requires an average of 300 man days of labor. This figure was reduced to averages of 115 days for clearing and burning the virgin forest, 20 days for cutting up stems of mature plants for propagation material and planting them, 85 days for chopping weeds and 80 days for harvesting. On old cropland approximately 360 to 400 man days were required to produce such a crop. The initial effort to clear the land was less, but considerably more time was spent in chopping back weeds with a machete during the subsequent years. Once established a field requires no attention other than occasional weedings until harvest time. If the stand is a relatively full one, as the plants grow taller and broader they tend to shade out weed growth.

Harvest and Preparation for Market

The harvesting of lonchocarpus roots is a task requiring stamina. The fresh roots of two-and-a-half-year-old plants will ordinarily weigh from one to five pounds. As a general rule, most of the roots spread out laterally but a few grow almost directly downward. The gatherer's job is to salvage as much of the entire root system as possible. To accomplish his work he first severs the trunks of the plant about a foot and a half from the ground with a few machete slashes. He then pries under the crown of the plant with a long, stout, sharp-pointed pole which he drives into the ground with several vigorous jabs. By exerting some leverage on the end of the pole he is able to lift the crown slightly above the level of the soil so that he can see where the main roots are attached. He then severs the roots on one side of the plant and pulls them from the ground individually. If they are very large roots or penetrate more than a few inches below the surface of the ground he may be obliged to pry them loose with his stick or dig them out with his machete. The roots still attached to the crown are more easily removed by pulling backward on the attached butt of stem and ripping them out of the soil, sometimes with the assistance of the digging stick or machete. The operation takes a strong back and arms, and only a man of considerable endurance can engage in this task for more than five or six hours a day. The average farmer gathers and carries away from the field about 125 pounds of fresh roots in a day's time. To facilitate carrying he securely ties his roots into a single large bundle bound with long pieces of forest liana.

By harvest time the average independent grower has had to borrow cash advances on his crop from his patron or from a local merchant. In payment of these debts he may deliver his roots to his creditor. He may, on the other hand, sell his entire plantation at harvest time to a representative of some commercial company. These representatives, known in Peru as "regatones", will contact the individual grower and offer him a price. If the proposal is accepted the planters' debts are paid to his creditors by the *regaton*.

Patrons, merchant creditors and the commercial houses represented by the regatones maintain crudely built shelters in the principal production centers where they collect and store the fresh root until they have enough to ship by steamboat to the port of Iquitos. Some patrons and regatones who operate on a small scale may even transport their collections by dugout canoe or balsa raft. When the roots arrive in Iquitos, those which are not already owned by the larger export companies are bought and stored for air-drying in the exporters' warehouses. Roots which are exported crude are kept in storage several months until their moisture content has been reduced to approximately 20% of their weight. (When fresh they contain about 60% moisture.) Then they are packed into bundles wrapped in burlap or unbleached muslin. On the ocean voyage they usually lose considerable moisture and arrive in the United States in a fairly dry condition.

In recent years a grinding industry has been established in Iquitos, Peru. Roots for grinding are first air dried, then chopped and oven dried before being passed into the mill. The final product, all of which is 200 mesh or finer, is packed into bags for shipment.

Selection of Superior Quality Strains

The commercial value of lonchocarpus roots on the United States market is determined by their rotenone content, even though insecticide manufacturers and entomologists recognize the secondary importance of the rotenoids. Consequently the growers of both lonchocarpus and derris are particularly interested in cultivating those strains which will yield roots of highest possible rotenone percentage. As with many other economic plants, the first major task of selecting superior strains from nature's miscellaneous variety was probably accomplished by primitive man. Perhaps in their search for effective fish poisons the aboriginal inhabitants of the South American rain-forests discovered and propagated some of the more potent lonchocarpus plants. The majority of contemporary commercial barbascales have been established from lines of plants perpetuated by the Indians and more recent immigrant settlers.

When the commercial possibilities of lonchocarpus production were recognized in both Brazil and Peru in the early 1930's the most enterprising mercantile houses, operating through their rural intermediaries, established collections of living plants from the areas where they purchased the best grades of roots. In Peru a few of these introduction gardens eventually expanded into community plantations where individual families now grow a few acres each and where the total area dedicated to the crop in some cases involves 1,000 to 3,000 acres.

In 1942 the Instituto Agronomico do Norte at Belem, Brazil, began a systematic study of hundreds of mature individual lonchocarpus plants of both *L. urucu* Killip and Smith, and *L. utilis* Krukoff and Smith, which had been brought to Belem by plant explorers. Chemical analyses of samples taken from the roots of these individuals revealed a range in rotenone content from 0.9% to 20.1% among 148 plants of *L. utilis* which were estimated to be between three and five years of age. Weights of fresh roots harvested from these individuals varied between 20 and 3,895 grams. At the same time 232 individual *L. urucu* plants approximately three to five years of age were studied in the same way. Their rotenone content ranged from a low of 2.2% to a high of 11.2% and fresh root weights varied between 25 and 6,420 grams. At the present time the average commercial

root shipments contain from 4% to 6% rotenone.

An interesting feature of the Instituto Agronomico do Norte's work is the observation that certain high root weight producing *L. urucu* strains may be more profitable to cultivate than the commonly preferred *L. utilis* which usually produces a higher rotenone content but less root weight during an equal growth period. As the Instituto Agronomico do Norte technicians emphasize, the commercial producer should be interested in achieving the highest total of rotenone per acre per year.

Work similar to that being done in Belem is being conducted by the Estacion Experimental Agricola de Tingo María in Peru and by the Estacion Experimental Agricola del Ecuador at Pichilingue on the Vinces River in Ecuador.

Bananas. The following are the principal varieties of banana cultivated in the American tropics.

Gros Michel. This variety, known also as the Jamaica, Martinique and Roatan banana, is the variety that has attained the greatest commercial importance and is nearly the only one commonly known in the United States. The "fruit is never allowed to ripen on the plant, as the skin bursts open and the pulp falls prey to insects and birds. In addition, the pulp becomes granular in texture, and the flavor is less palatable. Bananas are always cut green but at varying stages of maturity depending upon the ultimate destination. If the shipment is for European consumption, greener fruit is cut than that intended for the United States and Canada".

"The usual marketable bunch or stem of Gros Michel has from 8 to 10 hands, or clusters, each containing approximately 18 fruits, called fingers, making from 150 to 180 bananas in all. . . . Of nearly 90,000,000 bunches of bananas exported annually before the war from Mexico, Central America, the West Indies and South America, at least 90 percent were Gros Michel. The United States took roughly, 55,000,000 of the total amount".

Claret. This variety with purplish-red skin is little known in the North, but sometimes appears in markets at Christmas time. The flavor is similar to that of the Gros Michel, but the texture is rather gummy, and the bunches are smaller with fewer hands and fingers.

Lady Finger. Known also as Golden Early, Rose or Date banana, this delicious variety is only three to four inches long and is popular in Latin America. Its thin and easily bruised skin hinders profitable shipment.

Apple. Thin-skinned and similarly difficult to transport, this variety, too, is not known in northern markets. It is four to five inches long and has an apple-like odor and a rather granular texture.

The foregoing are but four of the 150 to 200 known varieties of the species *Musa sapientum* L., nearly all of which are food producers.

Cavendish. This one, known also as Chinese, Canary and Dwarf banana, is the variety *Cavendishii* of *M. nana*. It ranks second in commercial importance after the varieties of *M. sapientum,* and produces bunches of 200 bananas sometimes as large as those of the Gros Michel. The plants are only five to seven feet tall, however, instead of up to 25 feet as are those of Gros Michel. This variety is more important in southeastern Asia, lands of the central Pacific Ocean, Africa and the Canary Islands than in the western hemisphere.

Plantain. Plantains, known in several varieties according to shape, size and color of the fruit, differ from the foregoing forms in having to be boiled, fried or baked before being edible. They are all forms of the species *Musa paradisiaca,* and some of them yield the largest fruits of the banana family. These cooking bananas have for long been a basic food of hundreds of thousands of people in tropical lands. (*D. E. Farringer, Agriculture in the Americas 7(4–5): 63. 1947*).

Some Promising Insecticidal Plants

In addition to tobacco, pyrethrum and the rotenone-bearing plants of the genera Derris and Lonchocarpus, seventeen of which are discussed in this paper, have been found promising as sources of insecticides.

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Introduction

NEARLY 1,200 species of plants have been reported in the literature to be of possible insecticidal value (29), but of these only a few—tobacco, pyrethrum and the rotenone-bearing plants *Derris* and *Lonchocarpus*—are used extensively. It is the purpose of this paper to call attention to some of the other plants that seem to have sufficient insecticidal properties to justify further research to ascertain their possibilities in insect control. Although the entomologist now has DDT, benzene hexachloride, chlordane, hexaethyl tetraphosphate and other synthetics with which to fight pests, he needs additional weapons in order to wage war against an increasing number of insect enemies. The synthetics are specific in their action on insects, proving to be highly toxic to some species and practically inert to others. No one insecticide answers all purposes. In the development of new insecticides, those derived from plants deserve careful consideration because they are highly effective against many of our worst insect enemies, are harmless to other plants and are relatively non-toxic to warm-blooded animals.

The plants mentioned in this review are those which appear to be especially promising for use as insecticides. However, so little research has been done with plant constituents as insecticides that many additional plants will doubtless be found useful in the control of pests. A search for new insecticides among plants will amply repay the investigator who takes care to avoid the numerous pitfalls in such an undertaking (36).

Plants contain not only toxic materials valuable as contact or stomach poisons to insects, but also substances useful as synergists (sesamin), wetting and emulsifying agents (saponins), adhesives (rosin oil) and stabilizers (tannin) to be used with pyrethrum, rotenone or other insecticides.

In the following discussion the plants are treated alphabetically, according to family and to genus. A more logical arrangement would be according to the chemical nature of the insecticidal constituents in the plants, but the limited information on the chemistry of these compounds does not permit this classification. Also, insufficient work has been done with these plants to permit their grouping according to their action on insects.

Apocynaceae

Haplophyton cimicidum A. DC., called the cockroach plant, has been used since time immemorial in Mexico for killing cockroaches, flies, mosquitoes, fleas, lice and other insects. The reports by investigators on the insecticidal value of this plant differ greatly, probably because its chemical composition may vary with growing conditions, such as altitude and soil. Plummer (34) in 1938 reported the dried leaves to be toxic to the Mexican fruitfly. Water extracts of the stems of plants grown in Arizona were

highly toxic as both stomach and contact insecticides when tested against adult house flies. Crude "alkaloid" from this plant proved to be effective against most insects on which it was tested. For example, it was as toxic as pyrethrum to the squash bug and the blister beetle. Other efforts to isolate the toxic constituents were unsuccessful (11, 16).

Asteraceae

Heliopsis longipes (A. Gray) Blake grows in the vicinity of Mexico City where the roots are employed in the preparation of insecticides for local use. A specimen of the roots was sent to the Bureau of Entomology and Plant Quarantine at Beltsville, Maryland, under the name *Erigeron affinis* DC., but when a botanical specimen was received some time later it was identified as *Heliopsis longipes* by S. F. Blake of the Bureau of Plant Industry, Soils, and Agricultural Engineering.

The roots yielded about 1 per cent of an amide (3) which, on the basis of the mistaken identity of the plant, was called "affinin". This amide was later (4) identified as N-isobutyl-2,6,8-decatrienoamide, $C_{14}H_{23}NO$. Affinin has the same paralyzing action and toxicity to house flies as do the pyrethrins, and is also toxic to other insects, including codling moth larvae and several leaf-eating insects.

Bixaceae

The stems and roots of the Mexican plant *Ryania speciosa* Vahl. contain alka-

FIG. 1. Dr. H. L. Haller, chemist of the U. S. Bureau of Entomology and Plant Quarantine, with some thunder god vine, *Tripterygium wilfordii*, grown at Glenn Dale, Md., from cuttings obtained by one of the Department explorers in China where the powdered roots of this species have long been used as an insecticide by market gardeners. (*U.S.D.A. photo by Purdy*).

loids toxic to many kinds of insects and to rats. A proprietary insecticide prepared from this plant was first tested in 1943 against the European corn borer and found to give excellent control, being essentially equal in effectiveness to DDT (33). This material also proved to be toxic to the oriental fruit moth on quince (48). The method of preparing an insecticide from *Ryania* extract and its value for the control of many species of insects are described by Folkers *et al.* (18).

Unpublished results of tests made by the Bureau of Entomology and Plant Quarantine indicate that an extract of this plant is effective against cabbage worms, melonworms, squash bugs, codling moths and black carpet beetle larvae, but ineffective against house flies and both adults and eggs of the body louse. At present the chief use of *Ryania* as an insecticide is for the control of the European corn borer on sweet corn in New York and New Jersey.

Celastraceae

Tripterygium wilfordii Hook. f., lei kung ting or thunder-god vine, is widely cultivated in China where the powdered roots are used extensively for the control of vegetable insects. In 1939 powdered fresh small roots, grown from imported Chinese cuttings by the United States Department of Agriculture at Glenn Dale, Maryland, were found to be very toxic to first-instar larvae of the codling moth, the diamond-back moth and the imported cabbage worm. Alcoholic extracts of the roots were even more toxic. Small roots when powdered were about half as toxic as pyrethrum to the American cockroach, but the medium and large roots were non-toxic (47). Attempts to isolate the active principle, which belongs to the class of ester alkaloids, were unsuccessful, but an insecticidally inert red pigment, tripterine, was obtained from the root bark. This is the same pigment found in the root bark of the related North American bittersweet, *Celastrus scandens* L. (38).

Chenopodiaceae

Anabasis aphylla L., indigenous to the steppes of the Caspian region, contains

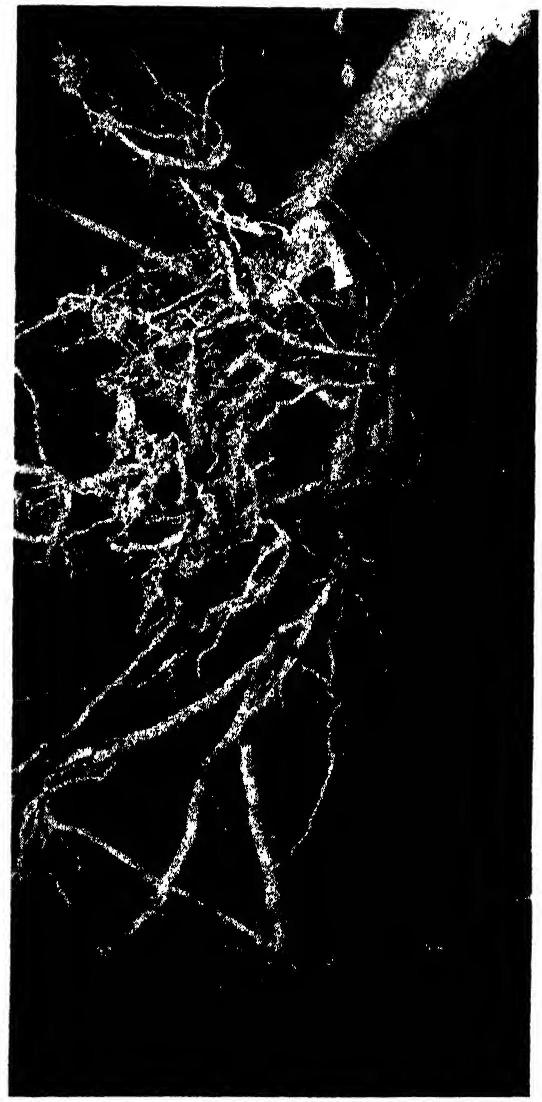

FIG. 2. Roots of the thunder god vine. Chemists and entomologists of the U. S. Department of Agriculture are investigating the possibility of preparing an insecticide from such roots. (*U.S.D.A. photo by Purdy*).

a mixture of alkaloids, chiefly anabasine which is a liquid isomer of nicotine and

closely resembles it in pharmacological and insecticidal properties. About 15 years ago the Russians marketed in this country an insecticide called "anabasine sulfate", 40 per cent solution, which was prepared from *Anabasis* and contained all the alkaloids naturally present in that plant, including about 32 per cent of the anabasine. Tests made by American and Russian entomologists with this commercial insecticide showed it to equal or exceed a 40 per cent nicotine-sulfate solution in toxicity to several kinds of aphids and other soft-bodied insects (35, 37). Laboratory tests with pure anabasine (7) showed it to be more toxic than nicotine to cabbage aphids, nasturtium aphids, pea aphids and citrus red mites, but less toxic than nicotine to celery leaf tiers, large milkweed bugs and spider mites. Anabasine proved to be less toxic than nicotine to codling moth larvae (39). The Russians withdrew anabasine from the American market about 10 years ago, and at present we are without a commercial source of this promising insecticide. Anabasine also is present in certain species of *Nicotiana* (40), especially *N. glauca* R. Grah., the tree tobacco of the Southwest. As much as 6.6 per cent of anabasine was found in the leaves of one of the unpruned hybrids *Nicotiana rustica* L. × *N. glauca* R. Grah, (49), and cultivation of this hybrid appears to be the best way of producing anabasine on a large scale.

Euphorbiaceae

The seeds of *Croton tiglium* L., which contain croton oil as specified in the National Formulary VI, are used in China as an insecticide. Spies (41) in 1933 reported that an acetone extract of the seeds was more toxic than derris extract to goldfish; also that croton resin was more toxic than rotenone. A chemical study of the resin showed that its toxicity is due to the presence of hydroxyl groups. Croton resin is highly vesicant, resembling poison ivy. Although complete methylation of the hydroxyl groups yielded a resin free from vesicant action, the product was also non-toxic (17, 42–44).

Ricinus communis L., the castor-bean plant, has long been reputed to have insecticidal value. In 1940 Holzcker (24) announced a proprietary insecticidal spray material prepared from the leaves, but the value of this has never been established. McIndoo (30) reviewed the literature and concluded that the reports of the efficacy of this plant in killing insects were greatly exaggerated. Haller and McIndoo (23) called attention to the fact that, although ricin, a protein, and ricinine, an alkaloid, are poisonous to vertebrates, little is known of their effect on insects. Both these principles occur in the seeds as well as in other parts of the castor-bean plant. Ricin was found to be non-toxic and ricinine to be highly toxic to codling moth larvae; both proved valueless when tested against house flies. Haller and McIndoo concluded that it is possible that an insecticidal principle is present in the castor-bean plant only under certain conditions with respect to variety, cultural practice and environment. It would appear that the accepted use of the castor-bean plant as a source of insecticide awaits the isolation, identification and methods of analysis of the specific substance or substances toxic to insects.

A valuable synergist for use with pyrethrum, namely N-isobutyl undecyleneamide, is prepared from isobutylamine and undecylenic acid which is obtained on pyrolysis of castor oil. Turkey-red oil, a useful emulsifier for insecticidal oils, is made by the action of sulfuric acid on castor oil.

Fabaceae

In 1928 the Division of Insecticide Investigations began work on a project to find plants that contain insecticidal prin-

ciples. Extracts from a wide range of plant species were tested on goldfish because it had been found that plant extracts non-toxic to fish are also non-toxic to insects, and this test permitted rapid screening out of the large number of materials of little promise. In pursuance of this project the writer, in 1931, collected specimens of *Amorpha fruticosa* L. in North Carolina which were tested by Spies (41). An acetone extract prepared from the whole plant and tested at the rate of 0.2 gram of plant per liter of water killed four goldfish in 278 minutes, as compared with 92 minutes for a similar extract of derris (1.7 per cent rotenone).

Inasmuch as several other plants proved much more toxic to goldfish than *Amorpha fruticosa,* it was not investigated further. In 1937 Moore (32) reported, on the basis of positive Durham tests, that rotenone is present in the roots, stems, bark and seeds of this plant from Nebraska. In 1939 Haller collected a sample of roots in Louisiana which were found to contain no rotenone (25). In 1942 Featherly of the Oklahoma Agricultural and Mechanical College suggested that, inasmuch as this plant is widely distributed throughout the Mississippi River Valley, its seed might serve as a source of rotenone during the war emergency. Seed collected by Featherly and others from widely different locations was examined in the Bureau. Although all the samples gave a positive Durham test and Gross-Smith-Goodhue test, no rotenone or any of the rotenoids could be isolated from any sample. A new glycoside, called "amorphin", $C_{33}H_{40}O_{16}$ (m.p. 151–151.5° C.), was isolated from the seed and was found to react positively to the color tests for rotenone (1, 2).

Brett (9) of the Oklahoma Agricultural Experiment Station has recently reported the results of a study of the insecticidal properties of *Amorpha* which reside largely in resinous pustules on the pods. Tests on 29 species of insects and mites showed that the extract acted as both a stomach and a contact poison, and that it was also repellent to house flies and horn flies for more than 12 hours when sprayed on cattle. Among the insects which are the most susceptible to the insecticidal principle, called "amorpha", are chinch bugs, cotton aphids, pea aphids, chrysanthemum aphids and spotted cucumber beetles. Amorpha had no effect on the skin, but poisoned a guinea pig which was fed an amount equivalent to four grams of pods.

Liliaceae

The seed of the lily *Schoenocaulon officinale* (Schlecht. & Cham.) A. Gray, sabadilla, has been used as an insecticide since the sixteenth century, but until recently this material was employed mainly for the destruction of lice on man and domestic animals (15). The shortage of rotenone caused by the outbreak of war in 1939 stimulated the testing of sabadilla against insects injurious to food crops, and lately it has been sold on a large scale for the control of hemipterous insects, such as squash bugs, chinch bugs, harlequin bugs and *Lygus* bugs (26).

Entomologists at the University of Wisconsin have been leaders in the investigation of the insecticidal possibilities of sabadilla and have patented a method of increasing its toxicity, which consists in heating the powdered seed in kerosene or other solvent to 150° C. for about one hour. If the material is to be used in dusting-powder form the powdered seed is heated without a solvent (5).

During 1945 and 1946 annual imports of sabadilla seed into the United States amounted to 120,000 pounds, mostly from Venezuela.

Pedaliaceae

The seeds of *Sesamum indicum* L. (*S. orientale* L.) yield sesame oil, an edible

semi-drying oil which is of interest to the entomologist because it contains sesamin, a powerful synergist for the active principle of pyrethrum flowers when tested on house flies. The value of sesamin for this purpose has been demonstrated (21, 22). Sesamin alone (0.2 per cent) in refined kerosene killed only 4 per cent of the flies, pyrethrum alone (0.05 per cent) killed 19 per cent, and a mixture of the

FIG. 3. A fruiting plant of sesame, *Sesamum indicum*, on the grounds of the Division of Agriculture for Littoral, west of Guayaquil, Ecuador. Sesame seeds have for generations been the source of an edible oil in the Orient. The oil contains an ingredient, sesamin, that strongly activates the well known insecticide, pyrethrum. (*U.S.D.A. photo by Mitchell*).

two in these concentrations killed 84 per cent. Sesame oil was an ingredient of the pyrethrum liquefied-gas aerosol bombs of which 40,000,000 were used by the armed forces during World War II. The original formula called for 2 per cent of sesame oil; later this was increased to 8 per cent.

Pinaceae

Pine oil obtained from *Pinus palustris* Miller is an ingredient of some sprays utilized for killing and repelling flies on cattle. Pine tar and pine-tar oil have been used in preparations for repelling blow flies from livestock. Of particular interest to the chemist is the recent development of a synthetic insecticide, $C_{10}H_{10}Cl_8$, made by chlorinating camphene, which in turn is made by isomerizing the pinene in turpentine. This chlorinated camphene is a light-yellow waxy product with a very mild piny odor containing 67 to 69 per cent of chlorine (45). Against household insects, such as house fly, German cockroach, black carpet beetle, furniture beetle, webbing clothes moth and bedbug, it displays high toxicity. It rivals DDT in its residual toxicity, but like DDT it has poor knockdown. Bishopp (6) reported that chlorinated camphene (called 3956) is slightly less toxic than DDT as a contact spray against adults of the yellow-fever mosquito, but against the body lice it is more toxic and more persistent than DDT. It has given promising results against insects attacking cotton, and its possibilities as an insecticide against a wide range of agricultural insect pests are being investigated.

Rutaceae

Phellodendron amurense Rupr., the Amur corktree, is a native of eastern Asia, but is cultivated as an ornamental in the United States. The fruit from a tree growing on the grounds of the Capitol, Washington, D. C., was found to be very toxic to mosquito larvae, house flies and codling moth larvae, but non-toxic to southern armyworm larvae (19, 46). The toxic constituent resides in the unsaponifiable portion of the oil, but no crystalline derivative of it could be

obtained. The interesting observation was made that the toxic constituent which, like the pyrethrins, is a fast-acting poison, is very toxic to house flies in acetone solution but not in kerosene.

The petroleum-ether extract of the bark of the southern prickly-ash, *Zanthoxylum clava-herculis* L., contains asarinin which is structurally related to sesamin and, like sesamin, markedly increases the effectiveness of the pyrethrins when tested against house flies. For example, in a series of tests refined kerosene containing 0.05 per cent of pyrethrins killed an average of 25 per cent of the flies after 24 hours, asarinin (0.18 per cent) killed 14 per cent, and a mixture of the two killed 88 per cent (20).

In addition to asarinin the bark of the southern prickly-ash contains a substance highly toxic to house flies which resembles pyrethrum in its action (27).

Simaroubaceae

The water extract of the wood of the trees *Aeschrion excelsa* (Swartz) Kuntze, Jamaica quassia, and *Quassia amara* L., Surinam quassia, finds some use in agriculture as an aphicide (10). It was concluded on the basis of a careful study of the insecticidal properties of quassia (31) that because of its low action an aqueous extract of quassia is much less reliable than nicotine sulfate; moreover, it is not a general insecticide for all aphids. The chemistry of quassia has also been studied (12–14). McGovran *et al.* (28) made laboratory insecticidal tests of a crystalline compound extracted from quassia wood, quassin, on the green peach aphid, the house fly, the Mexican bean beetle and the American cockroach, and found it to have little if any toxicity to these insects.

Quassin and related compounds from quassia are soluble in water and have an intensely bitter taste. These properties suggest their use in tree injection to control insect pests feeding on the sap. Plants whose roots were watered with a dilute solution of quassin were free of aphids, indicating that the quassin was taken up and translocated throughout the plant. Similar results were obtained when soluble selenium compounds were added to cultures of wheat. The advantage of quassin for this purpose is its non-toxicity to man.

Solanaceae

Bowen (8) found the dried leaves of the Australian plant *Duboisia hopwoodii* F. Muell. to contain 3.3 per cent and the larger stems 0.5 per cent of nornicotine. This alkaloid also is found in many species of *Nicotiana*. Smith and Smith (40) examined 29 wild species of the latter genus for alkaloids and reported that five species contained nornicotine only, and 18 contained a mixture of nornicotine and nicotine with the former predominating in most cases. Certain American tobaccos used in the manufacture of low-nicotine cigars have been found to contain as much as 0.7 per cent of nornicotine, and one-eighth of the total alkaloids in certain samples of commercial nicotine sulfate solution was nornicotine.

Nornicotine is more toxic than nicotine to the nasturtium aphid and the pea aphid; about equally toxic to the cabbage aphid, the citrus red mite, and the spider mite; and less toxic to the celery leaf tier, the large milkweed bug (7) and codling moth larvae (39).

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Cork. Since their inception in 1940 under the sponsorship of the late Charles E. McManus, former President and Chairman of the Board of the Crown Cork and Seal Company of Baltimore, Maryland, experimental plantings of cork oak (*Quercus Suber* L.) in the warmer parts of the United States have been expanded to include 22 States. This work has been carried on with the cooperation of Federal and State foresters, county farm agents and other governmental departments. For this purpose more than five tons of cork acorns were gathered in California in the autumn and winter of 1945–1946, and from 1940 to 1945 the distribution of domestically collected acorns increased from 500 pounds to a peak of 13,800 pounds annually. All these acorns, except approximately 200 pounds gathered yearly in Arizona and the South, were obtained in California from trees planted there years ago. In addition, acorns have been imported from Spain, Morocco and Algeria. Acorn germination varies from 50% to 80%.

Since 1940 virgin cork has been stripped from 516 trees of long standing, 20 of them in Arizona and the South, the others in California. These strippings, made from 1940 to 1945, removed 25,658 pounds of cork which has been manufactured into various products and found to be of excellent quality. Second growth cork of high quality has also been removed.

Successful experimental grafts of cork oak on both evergreen and deciduous American oaks have been made, and rooted cuttings have also been used for propagation purposes. Planting of acorns, however, is still the most effective means. (*G. B. Cooke, Scientific Monthly 61: 117. 1947*).

Use of Synthetic Hormones as Weed Killers in Tropical Agriculture

The introduction of chemical weed-control, through the use of highly effective, selective and inexpensive hormone herbicides, permits profitable crop production in the tropics where old tools and methods, combined with an increase in labor costs, have created a serious problem of eradicating the luxuriant growth of tropical weeds.

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Introduction

A FEW years ago my associates and I selected for weed-control experiments a field in which sugar cane had recently been planted. The cane was about one foot above the ground, and an abundance of small weed seedlings gave the field a greenish hue. The weather was warm, as it usually is in Puerto Rico, and the soil was rich and contained ample moisture. When we returned two weeks later, a lush blanket of broad-leaved weeds, some two feet in thickness, had all but covered the cane crop.

At that time the field was sprayed with an 0.075% aqueous solution of the ammonium salt of 2,4-D. Two weeks later, when the plantation was revisited, the weeds were down and the cane was again free to take full advantage of its favorable environment. Half a dollar's worth of 2,4-D per acre had restored the balance in favor of the cane crop.

Phenomenal weed growth is the rule rather than the exception in moist tropical regions. The farmer in these areas is obliged to wage a constant battle against weeds in order to keep them from gaining the upper hand over his crops. Archaic tools, such as the hoe and the machete, are still being widely used as the main implements in weed control. With field labor demanding a higher standard of living it is obvious that its work output has to increase in order to justify the higher pay and still make economical production possible. This cannot be done with the old tools and the old methods. Modern weed killers, in combination with modern applicators and techniques, offer a partial solution to this economic problem. Moreover they reduce the drudgery and back-breaking tasks traditionally associated with agriculture.

Development

Chemical weed control, and even the use of relatively selective herbicides, had its start in Europe at the turn of the century. Copper and iron sulfates were used to kill broad-leaved weeds among cereal crops. Later the practice found a limited use in the United States. More successful was the use of Sinox (sodium dinitroorthocresylate) which was first developed in France and later extensively used in the western United States (35). In the tropics chemical weed control was only sporadically used, probably primarily because of the availability of cheap labor.

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The discovery of 2,4-D has aroused great interest in tropical countries, and the indications are that chemical weed control will become standard practice in tropical agriculture. The reasons for this are at least twofold: first, 2,4-D is by far the best selective herbicide produced so far for tropical use; second, its introduction occurred at a time of social revolutions characterized by the disappearance of cheap coolie labor and increased demands for a higher standard of living by the common field laborer. This necessitates more efficient agricultural practices. Plantation managers were therefore in a receptive mood when the introduction of 2,4-D gave promise of greatly reducing the cost of weeding.

The substance 2,4-D (2,4-dichlorophenoxyacetic acid) is one of a great many synthetic plant-growth regulators. In 1942, at a symposium on hormones at Cold Spring Harbor, N. Y., P. W. Zimmerman of the Boyce Thompson Institute demonstrated some effects of this substance and of many others which he and his associates had synthesized (57). On tomato and other plants the 2,4-D was shown to cause abnormal growth of the youngest leaves. The effect was so striking that the plants appeared to be suffering from "shoe string" virus. Several other substances were shown to have this modifying effect on the growth pattern of leaves, but none was more active than 2,4-D. However, at that time it was not yet realized in this country that these substances could be used for herbicidal purposes. The symposium at Cold Spring Harbor was one of the last before the demands of war suspended the free exchange of information between scientists.

During the war the herbicidal properties of some auxins, especially cnlorophenoxy compounds, were realized in England (7, 33, 42) and in the United States (18, 29). In England sodium 4-chloro-2-methyl phenoxyacetate, now known as "methoxone", was developed since late 1941. In the United States the Special Projects Division of the United States Army tested over a thousand compounds for phytocidal activity; no substances which were substantially more toxic than 2,4-D were reported (3, 1). Toxic as the compound is to plants, investigations by the United States Department of Agriculture have shown that it is entirely harmless to man and cattle.

When 2,4-D first became commercially available in limited quantities for experimental purposes, its price, like that of many other synthetic growth regulators, was about one dollar per gram. When the value of 2,4-D to agriculture became apparent, large scale production by the chemical industry made the compound available in quantity and at a very much reduced price. At present it can be bought in ton lots and at a price which is only slightly above 50 cents per pound. To think of growth-regulating substances in terms of tons is indeed strange for hormone physiologists, accustomed to handling these compounds in quantities of micrograms. How rapid the development of 2,4-D for herbicidal purposes was is best told in the words of Kephart of the U.S.D.A. (24): "Thus a substance that was a chemical rarity less than two years ago is now being sold in hundreds of thousands of pounds and creating a whole new industry". In California alone over 50 different brands of 2,4-D herbicides were registered for sale by May 1947.

Action

It is known that the most effective poisons are found among those compounds which resemble, in terms of molecular structure, some hormone, vitamin or other substance necessary for the life of an organism (30, 56). Thus, for ex-

ample, it is believed that the sulfa drugs are such effective bacteriostatic agents because their molecular structure closely resembles that of para-amino-benzoic acid which is an essential growth factor for many microorganisms. Due to structural similarity of the molecule the organism cannot distinguish between the growth inhibitor and the growth factor, and soon the active groups in its protoplasm are saturated with the inhibitor, to the exclusion of the growth factor. This stops the normal function of the protoplasm and thereby prevents growth.

The effectiveness of 2,4-D as a phytocide is probably based on somewhat similar principles. There is ample evidence that in low concentrations 2,4-D acts like hormones of the auxin type. Like these auxins, 2,4-D in concentrations of the order of 5 to 10 parts per million is capable of causing growth curvatures in leaf petioles (57), of preventing preharvest drop of apples (5, 20) and of inducing flower formation in pineapples (46). However, 2,4-D in concentration of 250 parts per million will wipe out by one single spray application 80% of the weed population of the most common sugarcane weeds in Puerto Rico (47, 49).

What is it that makes 2,4-D so effective? In the first place it appears that 2,4-D, due to its close resemblance in molecular make-up to natural auxins, is readily taken up by plants and transported along their normal channels of hormone transport. Experiments at the Bureau of Plant Industry have made it likely that the substance is taken up and transported in the molecular non-dissociated form (55) and that it is transported away from the leaf, to which it is applied, to the growing and other regions of the plant in association with the translocation of sugars and along the same course (32). These observations have important practical implications, viz., alkaline sprays in which the major part of the 2,4-dichlorophenoxyacetic acid occurs in the ionized form are less effective (28), and any action which prevents the leaf from normally translocating its sugars will also tend to prevent the spreading of the herbicide throughout the plant.

In the second place, 2,4-D is an effective phytocide because after its molecules have been transported along the regular channels of hormone transport, they will arrive and apparently accumulate at the site where the natural hormones are most active, *i.e.*, in the protoplasm of the growing meristematic zones. This has been directly demonstrated by the Bureau of Plant Industry in experiments with a growth regulator containing radioactive iodine (55).

The normal function of hormones in the protoplasm is not exactly known, but there is good evidence that plant hormones regulate enzyme processes. In this respect plant hormones resemble animal hormones (2, 21). Among the enzymatic processes which plant hormones affect are some processes of respiration (6, 39, 40, 54). Recently two Chinese workers (23) have given us evidence that the toxic effect of 2,4-D may be due to its interfering with aerobic metabolism. They pointed out that rice, which is capable of anaerobic germination, is little inhibited by 2,4-D, while barley, which will germinate only under aerobic conditions, is strongly inhibited by 2,4-D.

It appears, therefore, that 2,4-D owes its effectiveness to its capacity to penetrate, in a physiological fashion, into the protoplasm of the meristem, thereby upsetting its normal functions, perhaps by interfering with aerobic metabolism. It is well to remember that meristems are among the most vulnerable parts of the plant, but often are so well protected by their location within the plant that they cannot be reached by contact sprays (10). It is only because

the hormone weed killers invade the plant through its normal channels of transport that these well hidden meristems are being reached. An example of this is the cyperaceous weed *Cyperus rotundus* (Fig. 1), known as nut grass in the United States and as "coquí" in Puerto Rico. Its meristem is hidden well below the surface of the soil and, in addition, is enclosed within the base of a

Fig. 1. ***Cyperus rotundus*, nutgrass or "coquí", two weeks after being sprayed with 2,4-D. The meristematic region, indicated by an arrow, has disintegrated completely. The plant shown on the left was split lengthwise to show better the region affected by the herbicide.**

structure which resembles a stem. No previous effective means of control existed for this weed, which in certain localities in the tropics is a major pest, but with 2,4-D complete eradication has now become possible (48).

In what manner could one visualize the effect of 2,4-D on aerobic metabolism? Some scattered experimental data are available. With the aid of these, together with information obtained in related fields, an attempt can be made to come to at least some tentative understanding of the action of 2,4-D on the metabolism of the plant cell.

Goddard, in a clarifying chapter on the utilization of liberated energy (15), states: "In many of the synthetic reactions of growth an increase in free energy occurs, and such reactions may only occur if they are coupled with an oxidative reaction furnishing the energy deficit". . . . "This widespread oxidative assimilation must be at the very basis of the chemistry of growth. . . ." Oxidative assimilation occurs in growing cells more frequently than in non-growing cells, and seems much more striking in plant than in animal cells (15). The fact that 2,4-D is toxic especially to growing cells and is specifically toxic to plants becomes understandable once one correlates the action of 2,4-D with oxidative assimilation.

The energy liberated in oxidation is utilized for the work of the cell. The energy coupling involved is the central problem of cellular respiration (15). One way in which the energy transfer can take place is by transfer of phosphate. Wildman and Bonner (54) have recently linked auxins to phosphate metabolism. From spinach leaves an auxin protein was isolated which appeared to have phosphatase properties and which could rapidly hydrolyze a number of phosphorylated compounds. Since it has been shown that 2,4-D has many properties of natural auxin it would not be surprising if 2,4-D, after combining with suitable proteins, would likewise be capable of stimulating the liberations of inorganic phosphate from phosphorylated compounds. This may involve direct release of phosphate-bond energy or transphosphorylation. Perhaps it would do so more strongly than the natural auxin indoleacetic acid. One reason for this would be that, as with hormones in general (21), indoleacetic acid is constantly being inactivated in the organism. Thus it has become known recently (41) that an oxidase exists which specifically inactivates the natural auxin indoleacetic acid. Many synthetic auxins would escape such inactivation. It is a fact that 2,4-D ranks among the auxins which persist longest in the plant. Perhaps there are also other reasons why 2,4-D would be a stronger agent in the hydrolysis of phosphorylated compounds than native auxin.

An exaggerated energy release in the organism may have far reaching consequences and may lead to the complete cessation of growth. A possible mechanism was suggested by McElroy (30):

"If *inorganic phosphate is increased* greatly by the hydrolysis of some phosphorylated intermediate (breakdown of high energy phosphates), then the glycolytic reaction may be so stimulated that the oxidative processes concerned in synthesis may not be able to compete with the available hydrogen acceptors and are consequently inhibited".

Here then we may have a biochemical basis for the understanding of the herbicidal action of 2,4-D. It now becomes understandable why the toxic action of the compound is slow. It also becomes understandable why, due to 2,4-dichlorophenoxyacetic acid, respiration, starch hydrolysis and depletion of food reserves are increased (4, 9, 38), while at the same time the growth process is in-

hibited. A somewhat similar case is known for sea urchin eggs where it has been found that dichloronitrophenol and other substituted phenols will completely inhibit cell division, while at the same time respiration is markedly increased (26).

Selective Action

Another interesting aspect of 2,4-D is its great selectivity. Crafts (10), in an excellent review on selective herbicides, has stated that: "the toxicant will always kill both weed and crop species if brought into intimate contact in sufficient concentration". This is true, no doubt. But it is more obvious with arsenicals or sulfuric acid than with hormone herbicides. The selective action of 2,4-D as a herbicide for sugar cane is such that it would require very special conditions, which rarely exist in practical agriculture, to kill, or even seriously damage, a cane plant with 2,4-D. Whereas the most common cane weeds of moist regions, such as *Commelina* (Fig. 2) and *Ipomea,* were killed with one single aqueous spray of the ammonium salt of 2,4-D at a concentration of 500 parts per million (Fig. 3), not the slightest damage was observed to the cane plant itself. Even concentrations as high as 0.3% which were sprayed on the cane plants themselves were entirely harmless (4, 47). Reports from Louisiana (8) also show that the water soluble salts of 2,4-D cause no damage to sugar cane, and that only when the 2,4-D was applied in high concentrations (0.5%) and in the form of the oil-soluble esters were lesions in the leaves observed.

In addition to sugar cane most other members of the grass family appear to be little sensitive to 2,4-D. Seedlings of grasses, however, although less sensitive than those of many broad-leaved plants, appear to be inhibited by 2,4-D (11, 17, 31, 33). The writer was shown by Crafts at his experimental fields at Davis, California, a series of wild oat plants which had germinated in a soil which was treated with high concentrations of 2,4-D. Not only was the germination much reduced, but the plants that did germinate had tubular leaves with the margins grown together in the same manner as found in coleoptiles and onion leaves. Members of the grass family may also be sensitive to 2,4-D during their reproductive stage. Rice was reported to be sensitive during the heading stage (36).

Among the grasses, all relatively insensitive to 2,4-D, sugar cane appears to be least sensitive. Even during its early stage of development 2,4-D sprays do not appear to affect its growth. In this respect it is well to remember that a young sugar cane field is physiologically not comparable to a field of germinating rice, barley or oats. Sugar cane is commercially propagated by means of cuttings, technically known as "seed pieces". Therefore, the young plants of cane are shoots developing from the lateral buds of the cuttings and not true seedlings. That such shoots might have a metabolism which resembles that of the adult plant rather than that of the seedling stage would not be surprising. For this reason it also becomes understandable why young cane plants are more resistant to 2,4-D than young plants of other members of the grass family which are propagated by seeds. Because in the sugar cane culture the flowers are of no consequence, the plant also escapes a possible injury by 2,4-D during the reproductive stage, as is known for rice (36). The special circumstances just mentioned make sugar cane during its entire growth cycle—under plantation conditions—practically insensitive to 2,4-D, at concentrations necessary to kill weeds.

This relative insensitivity is probably not due to the failure of 2,4-D to pene-

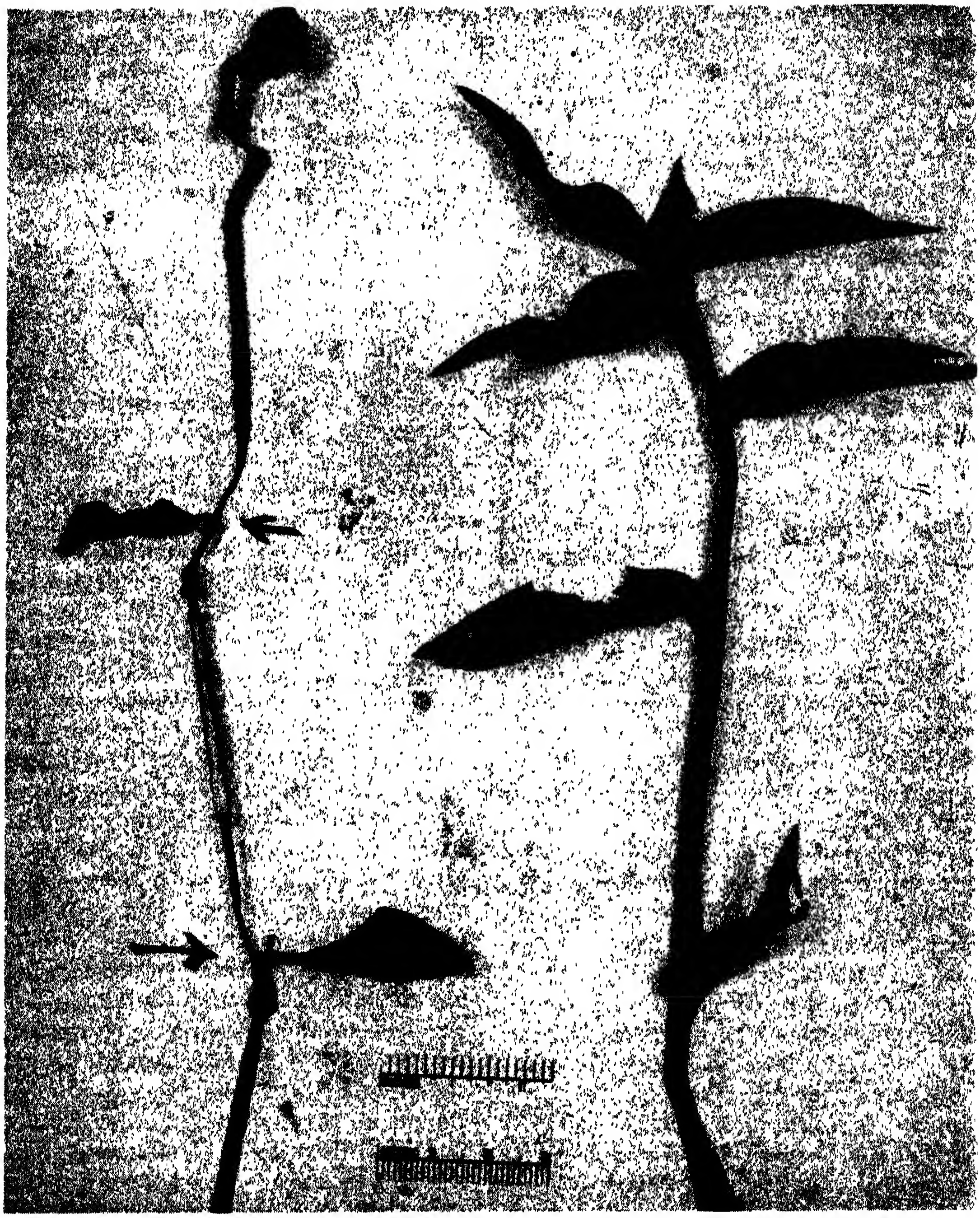

FIG. 2. *Commelina longicaulis*, wandering jew or "cohitre", two weeks after being sprayed with 2,4-D. The intercalary growth regions, indicated by arrows, have disintegrated completely. Right: untreated control.

trate the sugar cane plant. It is known that auxins, such as naphthaleneacetic acid, penetrate sugar cane stems (45). It is also known that other hormone-like regulators penetrate into barley plants, without, however, causing a significant reduction in their growth. The latter was shown by means of radioactive iodine which was used as a tracer in 2-iodo-3-nitrobenzoic acid (55). The

problem of why certain plants, at certain stages of development, are sensitive to 2,4-D, while other plants species are not, will probably be solved soon after we understand in detail where and how the natural auxins enter into the metabolic processes of the plant.

Members of the grass family are not the only plants which are relatively insensitive to 2,4-D. Several broad-leaved plants are also relatively insensitive to the compound. Even within the same taxonomic group some plants may be sensitive, while others are not. Thus within the legumes it was often found that plants of a herbaceous character are highly sensitive, while many of their woody representatives are not. Among the sensitive herbaceous legumes are the bean and *Stizolobium pruritum,* also known as "pica pica", which is feared by sugar cane workers for the stinging hairs on its pods (47). Among the legumes which resist 2,4-D are *Erythrina* species, which serve as coffee shade trees, and *Derris elliptica* (53), a woody creeper the roots of which yield the insecticide rotenone.

Coffee is another plant of great economical importance which seems to be immune to aqueous 2,4-D sprays. In coffee seedlings as well as mature trees, no damaging effects of 2,4-D were found (47). This is of considerable economic importance, as coffee plantations are habitually plagued by a number of harmful weeds which are difficult to eradicate by the primitive traditional methods: *Clerodendrum* threatens to overshadow young plantings; a variety of vines, among which *Ipomea* species are prominent, is an ever present menace to the crowns of mature coffee plants; and impenetrable bushes of the giant nettle, *Urera,* make the tasks of workers in coffee plantations difficult. All these coffee weeds are highly susceptible to 2,4-D sprays in low concentrations.

There is a striking difference in sensitivity to 2,4-D in various stages in the growth cycle of plants. We have already mentioned the grasses which are more sensitive in the seedling stage than later in life. It appears that broad-leaved plants, too, are more sensitive in their early stages of development than in later ones. Weeds in the seedling stage are known to be most susceptible to eradication by 2,4-D. The following may illustrate this:

Shortly after 2,4-D had begun to become available to commercial growers, the operator of a large sugar cane plantation asked for a sample of 2,4-D. This was promptly sent to him. The plantation in question was located in a moist region, where in our experience weed species occur which are highly susceptible to 2,4-D. For this reason we expected excellent results, and were much surprised when the grower reported that the new weed killer was no good since it had not killed the weeds as expected. Upon investigation we found that the planter, anxious to give the new herbicide a tough test, had applied the 2,4-D solution to a dense stand of tall, *mature* weeds. Such weeds are not much harmed by hormone herbicides. We left the plantation after having suggested that a new trial be started on a dense stand of *young,* actively growing weeds. The next report which we had from the grower was that he had ordered three tons of 2,4-D!

Mortality Curves

The sensitivity of a weed to 2,4-D sprays can be expressed graphically by plotting the percentage mortality against the concentration of the herbicide. The differences in sensitivity between plant species are reflected in mortality curves of different shapes, ranging from steep curves for the highly sensitive weeds to flat curves for the highly resistant spe-

cies. For practical purposes, however, the weeds of Puerto Rico have been divided into four sensitivity groups, each having a specific mortality-concentration curve (47, 49, and Fig. 3). Group I comprises plants which are highly sensitive to 2,4-D and which can be eradicated by concentrations of 0.05%. Group II includes plants which can be eradicated by concentrations of 0.15% 2,4-D. Group III contains plants which can be eradicated by concentrations between 0.2 and 0.3%; while, finally, group IV includes plants which are relatively in-

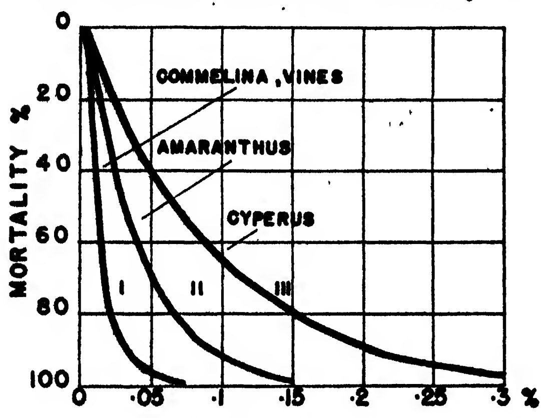

FIG. 3. For practical purposes the weeds of Puerto Rico have been divided into four sensitivity groups, each having a characteristic curve. The fourth group, not shown, consists of plants relatively insensitive to 2,4-D. Most of the common weeds in sugar cane and coffee plantations belong to group I and can be eradicated at a cost of less than 50 cents worth of chemical per acre.

sensitive to 2,4-D. The majority of the most noxious sugar cane and coffee weeds belong to group I, and can be eradicated at a cost of less than 30 cents worth of chemical per acre (47).

Succession

When growing conditions continue to be favorable for weeds, those killed by 2,4-D will be replaced by others which escape the lethal effect of the compound. It is a fact that the growth of grass weeds is indirectly promoted by 2,4-D sprays. This becomes understandable if one considers the following: A field of crop plants, together with its weeds, represents a plant population. The individual plant species which make up the population are in constant balance with each other. When one species is suppressed or killed the remaining members of the population compete with each other to take its place. This is illustrated by the happenings in the cane field which was mentioned at the beginning of this article. Before 2,4-D treatment this field was dominated by broad-leaved weeds, especially *Cleome*. A close inspection of the weed population revealed also the presence of numerous small weed grasses (*Digitaria*). These grasses, however, being sun lovers, could not develop because the fast growing *Cleome* plants overshadowed them. No sooner was the *Cleome* killed by the 2,4-D sprays than these grasses sprang into prominence. In the meantime, however, the sugar cane plants themselves had grown and were overshadowing and thereby checking the development of the weed grasses.

It would seem, therefore, that 2,4-D cannot be used as the exclusive method in a weed control program, and it will probably prove most efficaceous if mechanical weedings or applications of relatively non-selective herbicides be alternated with 2,4-D treatments (44, 48).

Possible Further Improvements

It is always hazardous to predict future developments, especially in a field as new as that of the hormone herbicides. The spectacular development of 2,4-D which we have witnessed in recent years could hardly have been predicted. Nevertheless, on the basis of present knowledge it seems possible to indicate

along which lines further development might take place.

Improvements in equipment are likely, as at present the characteristics of 2,4-D are not fully taken advantage of. One of these characteristics is that hormone herbicides are active in small quantities. Yet, because of their relatively low solubility in water, up to recently applications of from 100 to 300 gallons per acre have been necessary when aqueous sprays were used. Such sprays are popular in Puerto Rico at present because they allow purchase of the chemical in its cheapest form, the crystals of the 2,4-D acid. In addition, the solutions are easily made with the aid of small quantities of ammonia, and common applicators, ranging from knapsack sprayers to mechanical equipment designed for insecticides, can be used. Nevertheless, the hauling of the large quantities of water necessary for these sprays is hardly efficient. It should be possible to use the hormone herbicides in a much more concentrated form, perhaps using carriers other than water. Under such conditions it should be possible to reduce the amount of herbicidal material to a few gallons per acre. The equipment necessary for such operations is not generally available yet, but there is evidence that thought is being given to this problem. Thus Hamner and Tukey described recently an atomizing nozzle which makes it possible to apply concentrated oils, oil emulsions or water solutions of 2,4-D at as low a rate as three gallons per acre (16). Nozzles of this general type already have found wide application in California where low-volume spraying is becoming a standard practice. Tributyl phosphate has been found a suitable cosolvent of 2,4-D for use in mineral oils (14); at ordinary temperature this compound dissolves 36% by weight of 2,4-D. The triethanolamine salt of 2,4-D is so soluble that 0.7 lb. can be applied in less than two gallons of water (22), and some commercial preparations hold as much as 3.5 lbs. per gallon of concentrate.

Application of hormone herbicides in dusts is a possibility, and so are applications by means of fog generators (50) of the type used for developing smoke screens during the war. However, except when the plantations to be treated are quite isolated, there is real danger that clouds of herbicidal material may drift beyond their objective and cause serious damage to sensitive vegetation. Law suits may result which could easily offset the gains obtained by the more efficient method of weed control. In addition, the size of the particles produced by fog generators is naturally very small, and these will have such a high surface tension that they will tend to remain adrift rather than stick to plant material as intended.

Another field in which it seems much progress can be made is that of developing special herbicides for specific crops. Light oils, such as Stoddard solvent or stove oil (10, 27), are being used with success specifically for crops belonging to the Umbelliferae, such as carrots and celery. It has been reported from England (7) that 4-chloro-2-methyl phenoxyacetate is less likely to injure cereal crops than 2,4-D. Isopropylphenyl carbamate has become known, which when added to the soil is more toxic to grasses than to broad-leaved weeds (12), thus having a selective effect which is the reverse of that of 2,4-D, Sinox and several of the older selective herbicides. In addition, 2,4,5-trichlorophenoxyacetic acid has been reported highly toxic to potatoes, much more so than 2,4-D. These examples show that it is possible to match chemicals with vegetation, for either diminished or increased toxicity.

The use of activators and sensitizers is another field in which progress could be made. Two papers have already ap-

peared which indicate that the use of additives to 2,4-D may increase its effectiveness. Phenylacetic acid (25) and onion extract (28) were shown to have such effect. The writer was also shown at the Federal Experiment Station at Mayaguez the eradication of *Cynodon dactylon,* a weed grass, by a combination of 2,4-D and a low concentration of an arsenical (51). The grass is unaffected by 2,4-D alone and is damaged, but not eradicated, by the arsenical alone. A mixture of the two compounds seemed to eradicate the weed grass completely. This is a rather surprising observation in view of the fact that previous experiments have shown that 2,4-D will not spread inside a plant unless normal photosynthesis and translocation can take place (32). Arsenicals would be expected to cause such interference and therefore would tend to render 2,4-D less effective. In the example of *Cynodon,* cited above, the reverse was observed. Hence the arsenicals made 2,4-D toxic to the grass, or perhaps 2,4-D enhanced the toxicity of the arsenicals. From Louisiana it has been reported (8) that flame cultivation makes sugar cane plants more susceptible to injury by 2,4-D esters. The nodes are affected.

Last but not least, the way in which the hormone herbicides are used is subject to many modifications and improvements. One of the most promising techniques is that of pre-emergence weeding. By means of this method weed seedlings are killed before the emergence of the crop, so that the crop will not require the usual time-consuming and expensive hoeing and cultivation. Hormone herbicides, which persist under humid conditions in the soil for only a few weeks, are well suited to remove weed seedlings from the fields prior to planting. Because the action of these herbicides disappears from the soil before the crops are started, the use of 2,4-D is not restricted to non-sensitive crops, but may be used as well for crops sensitive to 2,4-D, such as leafy vegetables and beans. Under drier conditions, as occur in California, 2,4-D persists for longer periods in the soil, and diesel fuel oils may be used as pre-emergence sprays. Kephart (24), speaking about pre-emergence weeding, has estimated that: "This might well reduce the cost of producing field crops one-fourth".

Tropical use of 2,4-D and other hormonal herbicides is not restricted to the usual plantation and cash crops, but can be used for improvement of pastures as well. The author and his associates had an opportunity to help with brush eradication of pastures on a nearby island. Many thorny and undesirable shrubs which tend to hamper grass production (37) will regenerate from the stump after they have been cut down. Application of strong 2,4-D solutions on the cut surface prevented such regeneration and gave the pasture improvement a more permanent character. Similar results were reported in the continental United States (19).

When Not to Weed

In an article on weed control in the tropics mention should be made of the fact that under certain conditions weeds may be highly beneficial. This is especially so when they form a protective cover over the soil. In tropical regions rains are often torrential and the individual drops large. The impact of these drops on unprotected soils will invariably loosen soil particles. Once this has happened these particles are carried away by the run-off water, and large amounts of top soil are lost in an amazingly short time (12). In tropical regions with the sun overhead many hours of the day, overheating of the upper layers of the unprotected soil is common. Temperatures of over 110° F. can be found on an average day one inch below the surface of unprotected soils

(44), and even six inches below the surface, temperatures of 94° were recorded, which is 15° higher than maximal temperatures in soil protected by a mulch (52). It will be clear, therefore, that the dangers of excessive and unjudicious weeding are perhaps even greater in the tropics than in the middle latitudes. Before attempting weed control the farm manager has to ask: "Is weeding necessary, and if so, to what extent".

The rapidly growing weeds, discussed at the beginning of this article, which threaten the very existence of the sugar-cane crop is a clear-cut case in favor of drastic weed eradication. Similarly, the removal of *Commelina* and vines from sugar cane plantations, in order to have a clean surface at harvest time, is an obvious operation. A thick cover of weeds does not allow cane cutters to cut the stalks close to the ground, which would result in the loss of the valuable basal part of the stalk. In addition, the ratoon crop which follows a crop that is cut too high is subject to damage by wind which causes "falling" (43). The need for eradicating a number of noxious vines is equally clear: In sugar-cane fields the presence of *Stizolobium* ("pica pica") makes it impossible for men to move through the plantations without danger of injury by its stinging hairs; in the tree nursery the excessive shading caused by *Ipomea* and *Cissus* vines prevents the proper development of the young trees, while the tree-strangling habit of some of these vines tends to deform the trunks of the nursery stock; in coffee plantations these same vines tend to overshadow the crowns of the coffee plants thereby materially reducing their yield and often endangering the very existence of the plantation.

Less clear-cut cases for the need of weeding are found in the ground cover of coffee plantations. Here the giant nettle (*Urera baccifera*) and the dumb cane (*Dieffenbachia seguine*), both of which are injurious to plantation workers, have to be removed. On the other hand it is highly beneficial to leave a ground cover as a protection against soil erosion. *Commelina*, which is undesirable in sugar plantations, forms a beneficial ground cover in coffee plantations, and so do a large variety of other small weeds.

Excessive weeding, in the opinion of the author, is found in some Puerto Rican pineapple plantations. In these plantations clean cultivation is practiced. In order to accomplish this, a cultivator is pulled by an ox between the rows of pineapple plants at rather frequent intervals. The animal, however, refuses to move between these rows if the sharp leaves of the pineapple obstruct its path. Accordingly, men with machetes are sent into the fields to cut wide paths between the rows. In considering this situation one finds that much is lost and little gained. The cutting of the pineapple leaves reduces their photosynthetic area, which, in turn, results in a decreased fruit weight (46). It is also known that pineapple plants, being bromeliads—a family of epiphytes—have a poor and shallow root system. Moving the cultivator between the rows invariably causes root damage. In addition, removal of all weeds plus the cutting of the leaves causes the soil to be unnecessarily exposed to the sun. Knowing the characteristics of the root system of the pineapple it does not seem hazardous to venture the guess that soil protection would improve the growth of its root system.

All these disadvantages of clean cultivation in the pineapple field do not seem to bring with them any tangible advantage. The author became convinced of this when a plantation in the drier regions of Puerto Rico, in which periodic observations were made, was not weeded for a considerable time. The plantation was difficult to traverse on account of

the weed growth, and to an apostle of clean cultvation it must have presented a terrible sight. Nevertheless, its pineapple plants grew beautifully and produced an excellent crop.

Clean cultivation was abandoned in Java when the planters realized that the relatively slightly harmful effect of "benign weeds" is offset by their beneficial effect to the soil and to crop plants (34). Of course, no general rule can be made. The intelligent plantation manager, aided by specialists in weed control, will have to decide in practically every individual case whether weeding is really necessary, and if so, to what extent and with what methods.

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Utilization Abstracts

Wooden Boats of Ecuador. In the early wooden-ship building industry of Ecuador, beginning after the Spanish conquest in 1535, "hemp for cordage was grown in Chile, cotton for canvas in Peru, and tallow was obtained from cattle raised locally or imported from Chile. Underwater caulking was made of fiber from coconut husks; above the water line hemp was used. Pulleys and deadeyes were made of local wood". Today, despite the inroads of steel construction, there is still a great amount of wood ship construction for coastwise and river traffic. The woods principally used in this work are known as mangle, guayacan, black laurel, and amarillo. [The precise species can not be given—Ed.].

Mangle is one of the mangroves, which, unlike most of them, "grows very straight and to a great size in the coastal salt water swamps". The wood is very heavy, strong and moderately durable. According to local opinion it gives best service if stored under water for six months after felling. One fell-length piece, hand squared on all sides with an ax and adze, is used as the keel in boats, and must be replaced in three to eight years. Mangle is used also for stringers, clamps and shelves. "Other squared logs or timbers of amarillo and black laurel are brought in from more distant forests, whip-sawn into planking and decking, and stacked for air seasoning". And "men are sent into the nearby hills to obtain natural crooks of such 'incorruptible' species as guayacan, guachapeli, and madera negra, for stem, sternposts, frames, deck beams and knees. These parts are selected in the standing tree for their particular use in the finished boat, crooks being selected that are best suited to each member. After felling, the parts are worked and shaped to rough dimensions to reduce weight before being taken from the forest".

"The planks below the water line are of amarillo, a species highly regarded by Ecuadorian builders for its strength, durability, and resistance to attack by marine borers. Above water line black laurel is used, a species that gives good service but is not so highly regarded as amarillo. The same species are used for decking".

"Planking seams below water line are caulked with coconut fiber, a material said to be more durable under water than hemp caulking and, of course, much less expensive". "Above water line and on deck, hemp caulking is used, since it withstands alternate wetting and drying better than does the coconut fiber".

Black laurel is also used for planking and decking. (*L. V. Teesdale, American Forests 52: 410. 1946*).

Flax, Coir, Ramie, Henequen. Canada's 15,700 acres of flax will produce an estimated 930 short tons of graded scutched flax and 1,800 short tons of tow in the 1946–1947 season. "A new variety of flax has been produced by the U. S. Dept. of Agriculture under the name of 'Cascade'. It is claimed to be resistant to wilt, immune from rust, of tall growth, and to have an important bearing upon the future of flax production in the U.S.A.".

The 47 centers of coir coconut husk fiber yarn centers in Ceylon are enjoying a boom to meet increased demands for the material by gunny bag manufacturers in South Africa.

"The Florida Ramie Products Corporation has set up a plant for the decortication of ramie [*Boehmeria nivea*] at Belle Glade, Florida, with an estimated investment of 300,000 dollars.

"The plant reaches an hourly output of 500 pounds of peeled fibre after two months of operation. Its total production is being taken by the Navy for packing warship propeller shafts".

"Production of henequen [*Agave fourcroydes*] fibre in Cuba during 1946 is estimated at 15,000 metric tons, and the 1947 production is expected to be slightly larger. The greater part of the production is consumed locally. During the third quarter of 1946, 370 metric tons of henequen rope and twine were exported [from Cuba], principal destinations being the United States and Argentina". (*Anon., Fibres 8(3): 101. 1947*).